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UNITED STATES
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Albert M. Day, Director

Special Scientific Report No. 32

OYSTER BARS OF THE POTOMAC RIVER

By

David G. Frey

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Division of Fishery Biology

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INTRODUCTION

A survey of the Potomac River oyster bars made in 1928 revealed that oysters there were insufficient in quantity to support intensive oystering, and dredging for oysters was prohibited beginning in 1931. An improvement in the oyster beds within the next few years caused certain groups to agitate to have dredging again permitted. On January 21, 1942, the Maryland Department of Tidewater Fisheries requested the U. S. Fish and Wildlife Service to re-examine the Potomac River oyster bars to ascertain: (1) the present size of the oyster populations on the various bars; (2) the amount of recovery since 1928 and whether it has been great enough to warrant reopening the river to dredging; and (3) the effectiveness of past regulatory measures in maintaining a satisfactory level of oyster production. This investigation was begun by the author in November 1942 and completed in July 1943. Additional observations on the oysters of the Potomac River were made in 1943 and 1944.

In order that the results of this study could be compared with those of the 1928 survey, the same method of sampling was employed, namely, by small dredge. However, observations made during the present survey showed that the dredge is unsatisfactory for obtaining a knowledge of the actual numbers of oysters on the bottom because of the failure to catch everything in its path; hence, all figures for oyster populations in this report are relative rather than absolute.

The Maryland Department of Tidewater Fisheries furnished a boat equipped for this work as well as a crew to operate the boat and assist in making the counts and measurements of oysters and shells in the many dredge hauls.

DESCRIPTION OF WATERSHED[1]/

The Potomac River watershed of 14,500 square miles (slightly larger than the combined areas of Maryland and Delaware) is located in the States of Maryland, Virginia, West Virginia, Pennsylvania, and in the District of Columbia, and extends from Chesapeake Bay westward to the Allegheny Mountains which form the divide between the Potomac and Ohio River watersheds. The major portion of the watershed is located in the Applachian Mountain region where the larger streams run in a southwest-northeast direction along the axis of folding. Except for Occoquan Creek and Monocacy River, streams in the Piedmont and Coastal regions are small and of minor importance with reference to the size of their drainage areas and the amount of water they contribute to the total discharge of the Potomac.

Twenty-one miles east of Cumberland, Maryland, the main river is formed by the confluence of North Branch and South Branch. The nontidal section of the river is 266 miles long with a watershed of 11,580 square miles, and the tidal section is 117 miles long with an additional drainage area of 2,920 square miles. Little Falls just above Chain Bridge near the northwest boundary of the District of Columbia marks the upper limit of the tidal area. Of all the tributaries of Chesapeake Bay the Potomac has the second

1/ Data from Somervell, Brehon, 1931. Potomac River and tributaries including Occoquan Creek. House Doc. 101, 73d. Congress, 1st. Session.

largest mean stream flow, being exceeded only by the Susquehanna; but it has the largest area of brackish water suitable for the growth of oysters, amounting to more than 300 square miles. (48:224)2/

From Harper's Ferry, downstream, the Potomac River separates the States of Maryland and Virginia. A board of arbitration in 1877 placed the boundary between the two States at the extreme low water mark on the Virginia side of the river and from headland to headland at the mouths of the creeks along the same shore (48:223). Hence, except for tributaries like the Coan, Yeocomico, Nomini, Machodoc, and others bounded on both sides by Virginia land, the entire oyster producing area of the river lies within the State of Maryland.

OYSTER-PRODUCING AREA

Oysters grow in the Potomac River from the mouth to Maryland Point (48:217), 61 miles upstream. Upper Cedar Point, 54 miles from the mouth, marks the approximate upper limit of commercial production, there being only small scattered lumps in the next 7 miles. The main producing region of the Potomac extends from Lower Cedar Point to the mouth of the river, a distance of 44 miles.

Few oysters grow in the intertidal zone or in very shallow water, probably because of severe winter freezes which would kill all oysters exposed. Commercial production from this region is negligible. The depth of water over the bars examined during the survey varied from about 4 feet to 30 feet, with the majority of the oyster-producing areas occurring between depths of 5 and 18 feet.

Stevenson estimated (48:219) that there were 42 square miles of oyster dredging grounds in the Potomac, as compared with only 79 square miles for the rest of the Maryland part of Chesapeake Bay. It is certain that the total oyster-producing area of the Potomac River is considerably smaller than it was in the late 1800's. For instance, there are now no oyster bars along the Virginia shore from Ragged Point to Smith Point at the mouth of the river. Yet old timers remember a large bar at Hog Island, which has been nonproductive for more than 20 years. Similarly, as late as 1913 (36:200-201) dredge boats worked near Nomini Cliffs between Kingcopsico and Wakefield, but Luce in 1928 (40:147-148) found very few oysters in this region. The present survey disclosed several barren areas said by local oystermen to have been productive only a few years ago; and low population densities on other areas seemed to indicate that they too would soon lose their productive capacity. The overall picture is one of decline since the peak of production in the late 1800's.

In the present survey 5-1/2 square miles of oyster-producing bottom were examined. Twelve bars aggregating 2,910 acres were located along the Maryland shore and 5 totaling 480 acres along the Virginia shore. A number of bars on both sides of the river could not be completely surveyed in the time at hand.

2/ See bibliography

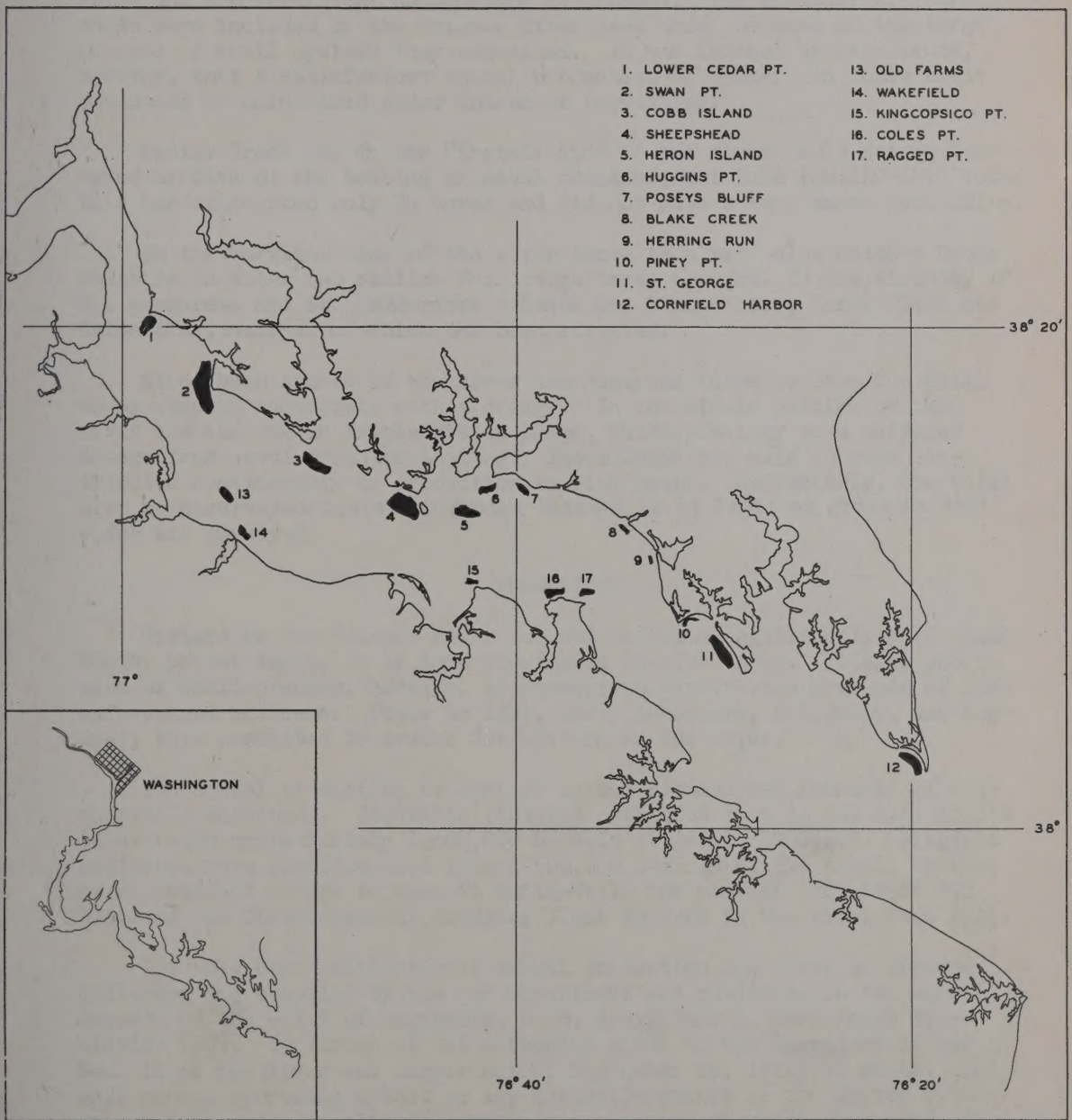


Figure 1.-- Location of Potomac River oyster bars examined in 1942-1943.

Figure 1.— Location of Potomac River oyster bars examined in 1979-1983.

There are at least 9 other oyster bars in the river in addition to those examined. Pascahanza Bar just below the Morgantown bridge, Popes Creek Bar of about 75 acres, Beacon Bar near Mathias Point estimated to be 200 acres in extent, Persimmon Point Bar of about 25 acres, and Upper Cedar Point Bar, 50-60 acres, all are located upstream from Lower Cedar Point and are relatively unimportant at present. For a number of years these were included in the Potomac River seed area, because of the large numbers of small oysters they contained. It was learned by experience, however, that a satisfactory annual production of oysters in these areas could not be maintained under intensive harvesting.

Rosier Creek Bar on the Virginia side of the river could not be surveyed because of the testing of naval ordnance, but Luce (40:140-141) found this bar aggregated only 24 acres and did not have a very dense population.

On the Maryland side of the river there is a bar below Smith's Creek which is in water too shallow for dredge boats to work. In the vicinity of St. Margarets and St. Catharines Islands are 2 more bars, Cords Flats and Chiseltine, neither of which has been surveyed.

Along both shores of the river are numerous lumps or bars too small to be sampled adequately with a dredge. In the middle portion of the river are the famous Kettle Bottom Lumps, which possibly have suffered damage from naval ordnance testing. These lumps are said to have contributed considerably to production in some years. Undoubtedly, the total area of unsurveyed oyster-producing bottoms is at least as great as that which was surveyed.

PRODUCTION

Oysters in the Potomac River can now be taken legally only with shaft tongs, patent tongs, or by hand picking in shallow water. Illegal operation of small dredges, however, is widespread despite the presence of law-enforcement officers. Prior to 1931, large schooners, skipjacks, and bugeyes, were permitted to dredge for oysters in the river.

The annual production of oysters in the Potomac was formerly of considerable magnitude. Stevenson (48:224) estimated that in the late 1800's it averaged approximately 1,600,000 bushels valued at $700,000. Virginia oystermen were credited with taking 500,000 bushels of the total. Oysters were abundant enough to make it worth-while for most of the 400 to 600 boats of the Chesapeake Bay dredging fleet to work in the river each fall.

The only other estimates of annual production are based on figures collected and compiled by the War Department and published in the Annual Reports of the Chief of Engineers, U. S. Army, Part 2, Commercial Statistics (30). By virtue of the authority given to the Secretary of War in Sec. 11 of the River and Harbor Act of September 22, 1922, 42 Stats. 1043, each person operating a boat on any navigable waters of the United States is required under penalty to submit an annual report on the quantity of material hauled in his boat. These figures at best are only approximations, because many of the oystermen keep no records of their catches, and the records are admittedly more nearly complete in some years than others.

Furthermore, the rather complicated tabulation in the annual reports is based on the origin and destination of the cargoes, so that one cannot always be certain he is dealing only with oysters caught in the central part of the Potomac. Despite these limitations and deficiencies, the curve of annual production based on these reports shows trends which appear to be correlated with known periods of setting and oystering discussed in the following pages.

Figure 2 shows that production in the central portion of the Potomac in recent years declined from a peak of 950,000 bushels in 1927 to a low of less than 50,000 bushels during the years 1931 through 1933. There was an increase in production to 640,000 bushels in 1938, followed by another decline continuing through 1942. Production in 1943 was greater than in either of the previous two years.

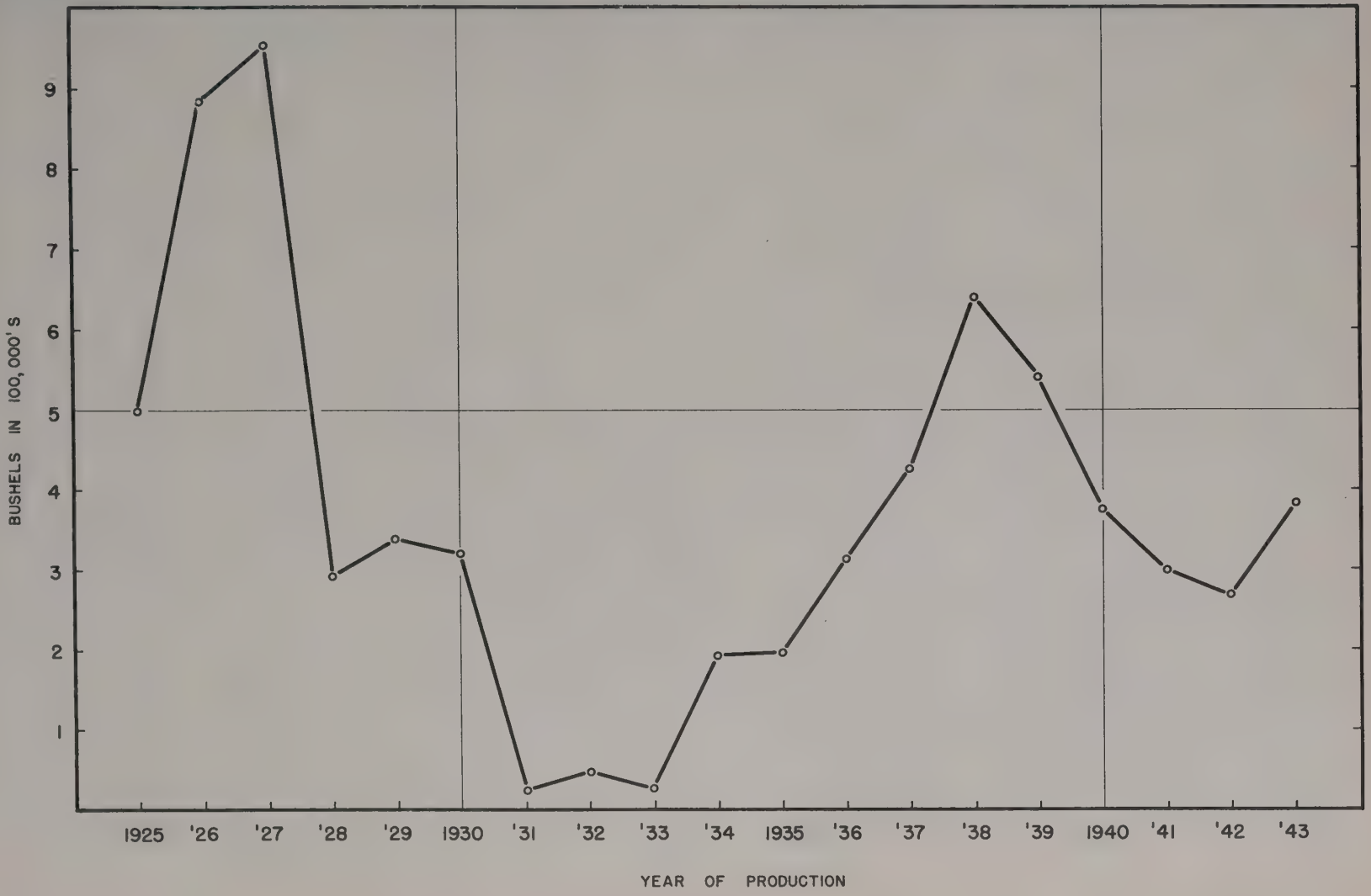
Until 1931, the large, Bay dredge-boats worked in the river each fall. Although prior to this time the trend of production had been downward, occasional good years caused optimistic notes to creep into the Annual Reports of the Maryland Conservation Department and Commission: 1918 (2:12-13) "The supply (of oysters) i the Potomac River has not only been greater than ever before, but has been of better quality and larger size"; 1925 (3:11) "...Potomac River is still regarded as the best oyster dredging area in the Chesapeake"; 1926 (4:9) tongers removed $100,000 worth of oysters from the dredging grounds between September 15 and November 1, the opening date of the dredging season. The oyster bars in the river were regarded as the most important dredging areas left in the Bay.

In November and December, 1928, at the request of Maryland and Virginia officials, a biologist from the U. S. Bureau of Fisheries (now incorporated into the Fish and Wildlife Service) examined the oyster bars in the central portion of the river (40). All the bars were found to be greatly depleted, few areas containing more than a bushel of marketable oysters per acre, determined by dredging. Cultch material was likewise scarce. To help rehabilitate the bars it was recommended that dredging be prohibited for at least 3 years, and that extensive plantings of shells and seed oysters be made, at an estimated cost of $66,000 for reshelling the bars and $80,000 for planting seed oysters (7:21).

Oyster bars in county waters did not share the depletion exhibited at this time by the bars in the main stream. Commissioner Swepson Earle of Maryland stated that the tributary bays and rivers in St. Marys and Charles Counties, used exclusively by tongers, were all supplied with oysters, supposedly a result of the program, begun in 1927, of planting shells and seed oysters on the bars of the State (6:13).

At the time the river was closed to dredging in 1931 Maryland Fisheries (17:14) reported that an oyster dredger could not make a livelihood on any of the bars in the river. Hence, the small annual production in the years 1931 through 1933 shown in figure 2 resulted not only from decreased fishing effort through the elimination of the dredging fleet but also from an actual scarcity of marketable oysters.

Figure 2.-- Annual production of oysters from central part of the Potomac River.



Good sets of oysters in 1930 and 1931 (8:15-17, 9:23) increased the population densities on the bars, resulting in a gradually increased annual production as more and more of the oysters became marketable. The peak production in 1938 could very well have been dependent chiefly on the 1930 and 1931 year classes.

Practical oystermen agitated to have the bars reopened to dredging. In late October 1932, a committee from Somerset County, Maryland, together with several State officials, examined the Potomac River bars and found that Sheepshead, Swan Point, Lower Cedar Point, Ragged Point, and Cobb Point bars were covered with sufficient oysters to yield 75 to 125 bushels per day per dredge boat, a great improvement over the conditions found by Luce in 1928. Tongers were making a satisfactory livelihood on the bars in the vicinity of Blakistone Island, Huggins Point, and Heron Island (10:18-20, 17:13-15).

Following 1938, there was a decline in annual production, probably resulting from continued harvesting of the 1930 and 1931 year classes with no other heavy sets contributing to production. The increased catch of oysters in 1943 may have been the result of increased fishing effort stimulated by the high prices of a heavy market demand, or it may have resulted from the observed heavy set of 1941 beginning to enter commercial production. In the latter event production can be expected to increase slowly for a few years before again declining.

HISTORY OF REGULATION AND MANAGEMENT

Effective management of the Potomac River oyster fishery has been especially difficult because of peculiar legal conditions. A compact ratified by Maryland and Virginia on March 28, 1785 states (21:211-212):

"Seventh-- The citizens of each State (Maryland and Virginia) respectively shall have full property in the shores of Potowmack river adjoining their lands, with all emoluments and advantages thereunto belonging and the privilege of making and carrying out wharves and other improvements so as not to obstruct or injure the navigation of the river but the right of fishing in the river shall be common to and equally enjoyed by the citizens of both States. Provided, That such common right be not exercised by the citizens of the one State to the hindrance or disturbance of the fisheries on the shores of the other State; and that the citizens of either State shall have the right to fish with nets or seines on the shores of the other.

"Eighth-- All laws and regulations which may be necessary for the preservation of fish or for the performance on Quarantine in the river Potowmack or for preserving and keeping open the channel and navigation thereof, or of the river Pocomoke, within the limits of Virginia, by preventing the throwing of ballast, or giving any other obstruction thereto, shall be made with the mutual consent and approbation of both States."

In return for granting Virginia equal fishing rights in the Potomac, Maryland was given unrestricted access to Chesapeake Bay, the entrance of which lies within the former State.

Only residents of Maryland may fish in the tributaries on the Maryland side of the river, and only Virginians may fish in the tributaries on the Virginia side, but any licensed resident of either State is permitted to catch shellfish and fin fish in the main part of the river. Until concurrent legislation referring specifically to the Potomac River is passed on by the two States, a fisherman or oysterman is bound to obey only the laws of the State of which he is a citizen. Resulting disparities before the adoption of concurrent legislation made even an attempt at law enforcement difficult, and made it likewise difficult for each State to command respect for its laws in its own intrastate waters (1:7-10). Stevenson (48:224) reported that in 1893, although oystermen of both States worked side by side in the Potomac, the Marylanders paid a boat license of $3.00 per ton, whereas Virginians were required to pay only $1.00 per ton. Marylanders were requested to cull all oysters less than 2-1/2 inches in length while the Virginians could keep oysters of any size.

A further barrier to effective cooperation between the States has been the fact that the Virginia legislature meets only in even-numbered years and the Maryland legislature only in odd-numbered years. It is little wonder that there has been no real management of the Potomac River oyster resources involving the planting of seed oysters and shells. Only a few regulatory measures regarding seasons, gear, and size of oysters have ever been agreed upon by the two States.

For almost 130 years, the Potomac oyster fishery drifted along with no regulation except that imposed by the Laws of the separate States, and as already stated enforcement of the latter was difficult. As early as 1884 Brooks had written (32:7):"...we recommend that, inasmuch as the State of Virginia has prohibited dredging in her waters, the State of Maryland approve the existing law of Virginia so far as it relates to dredging in the Potomac River and its tributaries, and we also recommend that the General Assembly enact a law of similar tenor prohibiting dredging in the Potomac River and its tributaries, to take effect so soon as it shall be approved by the State of Virginia." Almost 50 years were to elapse, however, before Brooks' far-sighted recommendation was put into effect.

Neither State by itself has been willing to do anything about the main part of the river. Baylor (31) surveyed the natural oyster beds in the inland waters on the Virginia side of the river, but did not report on those in the main stream. Yates (54,55), likewise, in his survey of oyster bars of St. Marys and Charles Counties in Maryland surveyed only those tributaries lying entirely within the county waters.

Not until 1912 were the first concurrent laws adopted to regulate the fishery. These included: (1) a 2-1/2 inch cull law; (2) establishment of a seed area north of a line from North Point at the mouth of Upper Machodoc Creek to Lower Cedar Point, in which only tongs could be employed for taking oysters: (3) stiff penalties for disregarding the various laws: (4) joint police protection by the two States (21:186-195, 20:58-61). In 1916 (1:7-10) a conference between the Maryland Conservation Commission and the Virginia Commission of Fisheries resulted in clarification of some of the concurrent laws and the resolve to enforce them uniformly.

Even before the 1928 survey demonstrated the need for such action, the problems of shelling the Potomac River oyster bars and setting aside certain of them for rehabilitation were discussed by the Maryland and Virginia authorities, but no definite action was taken (5). Immediately after the survey, as directed by Joint Resolution No. 12 passed by the 1929 session of the General Assembly of Maryland, Commissioner Earle conferred with the Virginia Commissioner of Fisheries and various legislative committees in Virginia for the purpose of dividing the financial burden of rehabilitating the bars, but no appropriations were made by either State (8:15).

The only concrete action taken on the basis of the 1928 survey was the closing of the river to dredging. Virginia, in 1930, passed a law prohibiting dredging in the river, and Maryland concurred, in 1931, with Senate bill 192 (14:1-3).

An apparent improvement in the oyster situation in 1932 (see p. 8) led officials from the two States to agree that implements other than tongs should be permitted in obtaining oysters from the deeper bars of the river, although both commissioners believed it would be a mistake to permit the reopening of the Potomac under the same conditions existing prior to the closing (10:18-20). Three separate bills, one of which was proposed by the Maryland Conservation Department, to permit limited dredging or scraping, using light gear, were presented to the 1933 session of the Maryland legislature, and all were defeated, chiefly through the influence of Eastern Shore interests (11:21-24). Since that time every Maryland legislature has witnessed a bitter battle to permit dredging or scraping in the Potomac River, but no session through that of 1943 has passed a bill legalizing this method of oystering.

Virginia, on the other hand, passed a bill early in 1934 permitting handscraping in the Potomac. Maryland did not concur, however, because the bill was said to discriminate against the Eastern Shore oystermen, who could not profitably work the bars with the light gear and small boats permitted (19:1-2).

As soon as the river was closed to dredging in 1931, illegal handscraping immediately presented a difficult problem of law enforcement (15:7, 16:10). In late November 1932, several Maryland inspectors were fired upon by handscrapers (18:19). A police boat armed with a machine gun was sent to help break up the poaching. Heavy market demand for oysters, with high prices was especially conducive to this illegal method of oystering in the fall of 1943, at which time handscraping was observed on several occasions by the author, and was even reported in the trade journals as being widespread (22:77, 25:66). An example of the flagrant violation of the law is given in the following quotation from Fishing Gazette (24:58): "A number of large skipjacks powered with gas engines of various makes and sizes and equipped with large dredges, are dredging every night on the Potomac River oyster rocks, from Colonial Beach down to the mouth of the river. They are making big catches, say our run-boat captains, and getting away with them despite the vigilance of the oyster police. Consequently, oysters are getting scarcer every day on the river beds.

"Because of this growing scarcity, Potomac tongers from Tangiers, Saxis, Smith's Island, and elsewhere are converting their boats into hand-dredgers and are now working the tonging rocks both night and day ..."

The 1944-45 oyster season in the Potomac has been no different in this respect from any other as evidenced by the following statement from the Atlantic Fisherman (23:30): "The tongers that are still on the river are converting their boats into hand-dredgers and are working the oysters rocks at night. Thus far they have done but very little better than the tongers. However, dredgers are making big catches on the Maryland side of the river from Swan Point down to its mouth. They are catching from 50 to 100 bushels of oysters a day and selling them for $1.85 and $2.00 a bushel."

Each year before the start of the oyster season both States resolve to keep handscraping at a minimum, but each year turns out to be little different from the preceding. Several of the patrol boats in the river are armed with machine guns and two-way short wave communications, but even crews in boats so equipped have been able to do little more than prevent handscraping in the immediate vicinity of their boats. The net result is that there has been little effective law enforcement in the central part of the Potomac.

SALINITY

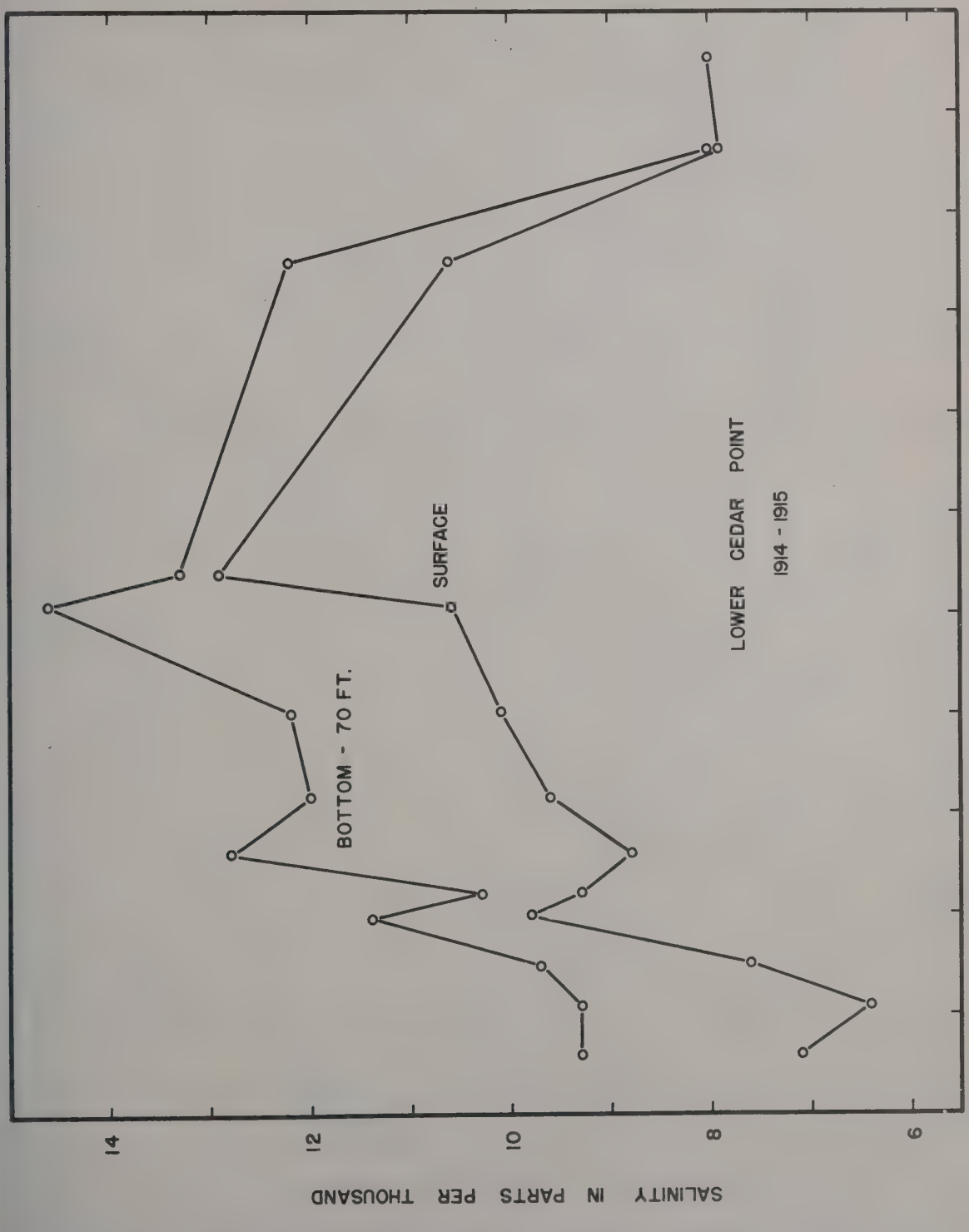
Because the oyster-producing region of the Potomac extends from the mouth of the river almost to fresh water and is subject each year to varying conditions of salinity, stream flow, and temperature, it is necessary to consider these factors of physical and chemical environment to obtain a more comprehensive understanding of oyster biology in the various parts of the river.

Salinity records for the Potomac river are fragmentary and nearly all unpublished. Collins (33) determined densities at various depths and stations along 3 cross sections. Grave (38) had samples collected at two-day intervals at each of three lighthouses on the river to determine approximate maximum and minimum limits of salinity. Stiles and Sale (50) and Stiles (49) determined chlorinity of the water by titration at various stations from Washington to the mouth of the river. Ritter (44) made numerous series of hydrometer readings in connection with the sanitary survey of the Potomac by Cumming (36). Wells, Bailey, and Henderson (52) regularly visited 3 stations at the mouth of the river during their study of the salinity of Chesapeake Bay. The U. S. Naval Powder Factory at Indian Head, Maryland, has had a recording salinity meter in operation for several years, and, finally, there are the determinations made by Luce (40) and the author (1942-44) during the surveys of the oyster bars of the river.

Combining the data from all these sources, it is learned that the recorded salinity of the bottom water at the mouth of the Potomac has varied from 9 to 21 o/oo and at Lower Cedar Point Bar, the uppermost bar examined in the two oyster surveys, from 3 to 15 o/oo. In general, the salinity is lowest in spring and early summer at the time of the heaviest runoff from the watershed. During the remainder of the year the salinity slowly increases, reaching a maximum usually in late fall or winter. For example, the lowest recorded salinities were observed in April 1912 and April 1913 after periods of comparatively high runoff, whereas, during the second half of 1914 salinities gradually increased as a result of low stream flow, culminating in November and December of that year in the maximum values recorded for the river.

The junction between fresh water and salt water, known as zero salinity,

Figure 3.-- Surface and bottom salinities at Lower Cedar Point during period June 1914 through April 1915, based on Ritter's observations.



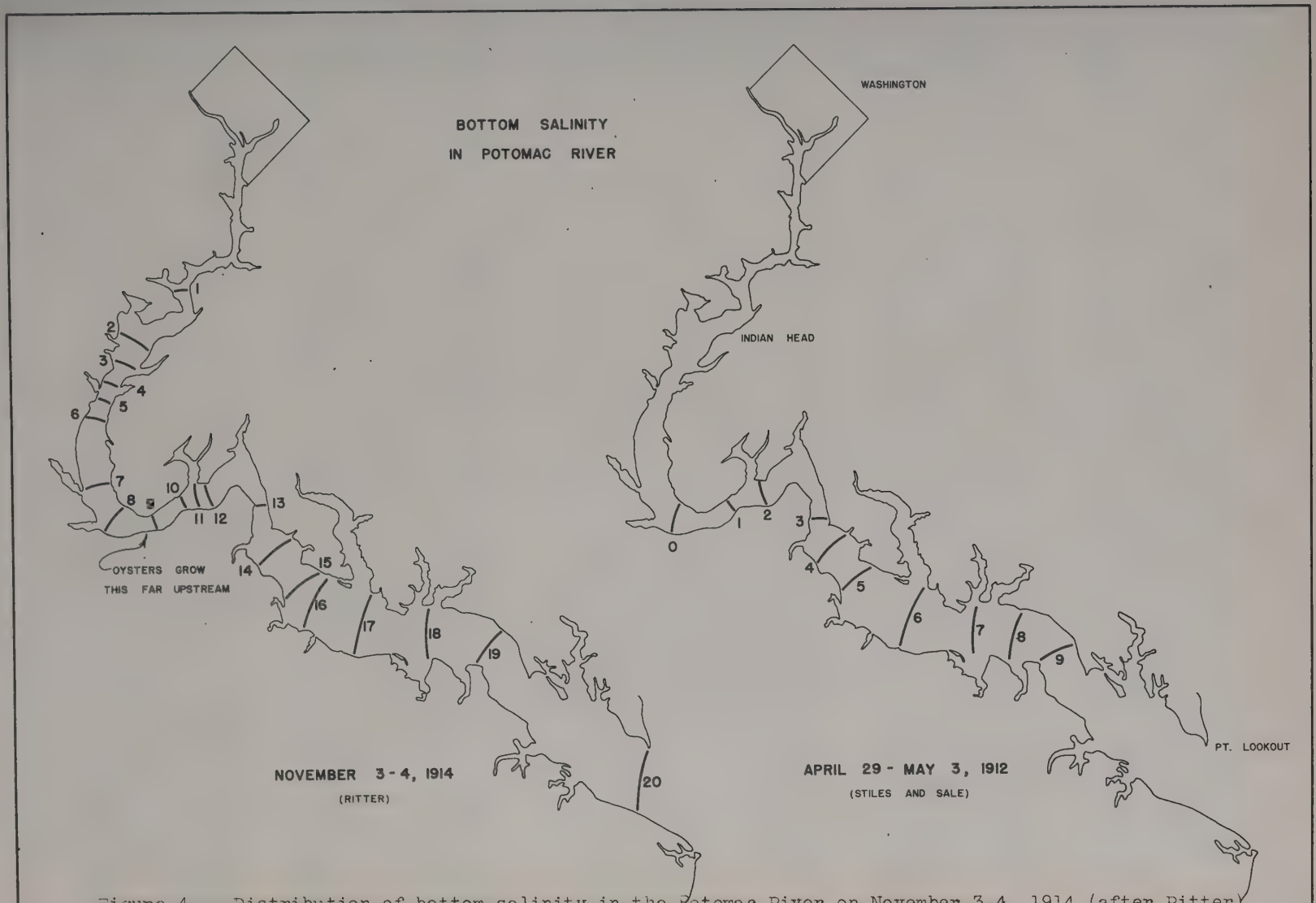


Figure 4.-- Distribution of bottom salinity in the Potomac River on November 3-4, 1914 (after Ritter) and on April 29 - May 3, 1912 (after Stiles and Sale).

varies in its position upstream or downstream depending on the amount of discharge from the Potomac watershed. In general, it occurs farthest downstream in spring during the period of maximum runoff and farthest upstream in late fall and winter following the low runoff period of the summer and autumn. It appears likely from the records available that in spring fresh water usually extends downstream to Upper Cedar Point. On April 30, 1912, fresh water extended down to Thomas Point, a few miles above Maryland Point, and on April 15, 1913, zero salinity occurred near Metomkin Point, several miles below Maryland Point (50).

During floods and freshets preceded by periods of high stream flow, zero salinity can be forced downstream into the oyster-producing region, sometimes resulting in mortality among the oysters. Salinity records are lacking for the duration of the actual flood periods, but the record-breaking flood of March 1936 was reported to have caused severe mortality of oysters in the Potomac as far downstream as Cobb Island Bar (12:26). Cumming (36:225) considered Popes Creek as the upper limit of sustained oyster growth, and observed that, "Oysters do not, as a rule, grow here to marketable size, owing to freshets which occur every year of so."

Normally, in fall and winter brackish water extends upstream at least to Indain Head (84 miles from Chesapeake Bay). In November and December of 1930, the year with lowest recorded summer runoff, salinity was 5 to 6 o/oo in the intake water at the U. S. Naval Powder Factory at Indian Head. On December 9, 1914, bottom salinity at this location was 5.2 o/oo (44). In both these years, the driest two on record, brackish water extended to or almost to the District of Columbia. On December 4, 1912, salt water reached Whitestone Point, a short distance above Indian Head. At other times (October 1913, 1917, and 1918), following summers with average runoff, Indian Head marked the approximate upper limit of brackish water, 0.3-0.4 o/oo salinity having been observed here at those times. On December 18, 1931, the salinity at the Indian Head intake was 2.54 o/oo and on September 28, 1932, it was 2.02 o/oo.

Records obtained at Indian Head with a salinity meter, in operation since 1938, show that during the period 1938-1944 salt water had not extended this far upstream from mid-March through August, but that beginning in the first half of September salt water usually appeared and slowly increased in concentration. The maximum for any particular year was reached as early as November 10 in 1938 (1.73 o/oo), and as late as January 3 in 1944 (1.98 o/oo). At no time during the winter of 1942-43 was brackish water found at Indian Head, demonstrating that salt water does not invariably extend this far upstream in winter. The highest salinity recorded at Indian Head during these years was 2.85 o/oo on December 8, 1941.

Figure 5 summarizes the observed range in bottom salinity along the 117-mile, tidewater section of the river. Although the records are fragmentary it is felt that the upper line of the figure represents very nearly the probable maximum salinity in the river since it is based primarily on records obtained in 1914, the year of second lowest runoff on record. The lower line in the figure, however, very likely represents only average minimum conditions because no salinity records are available for very wet years or flood periods. At such time, the salt concentration in the river would be expected to be the lowest.

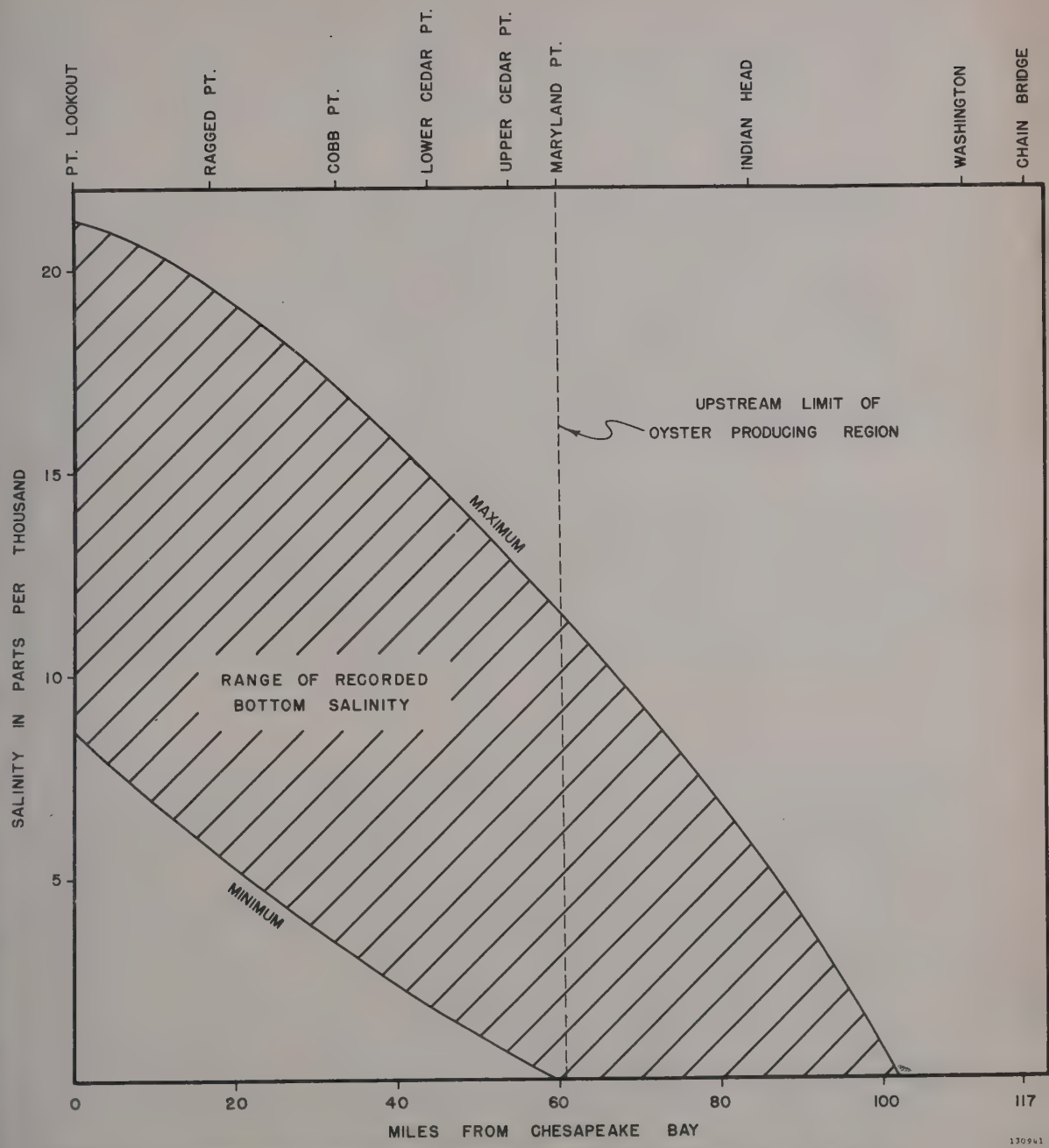


Figure 5.-- Range of recorded bottom salinity in Potomac from mouth of river to Chain Bridge at upper limit of tidewater, based on observations by Collins, Grave, Stiles, Ritter, Wells et al, Luce and the author.

Except during periods of strong wind, when the water was very nearly isohaline from top to bottom, salinity in deep water was frequently up to several parts per thousand greater than at the surface. Such slight differences in salinity which, likewise, have been commonly observed in other estuaries result from the tendency of the denser salt water was to move along the bottom of the river channel and the less dense fresh water to remain at or near the surface.

Salinity distribution across the river is almost uniform. The cross section at Point Lookout examined by Collins (33) showed the salinities on the Maryland side to be only slightly greater (less than one part per thousand) than those at corresponding depths on the Virginia side. At Piney Point, the water on the Maryland side of the river was likewise more saline than that on the Virginia side, whereas, just above Blakistone Island, water on the Virginia side had a slightly higher salinity. Data from Wells, Bailey, and Henderson (52) for 3 stations near the mouth of the river also show for nearly all series of observations a slightly higher salinity (usually less than one part per thousand) on the Maryland side of the river than on the Virginia side. These differences, although slight, may indicate a tendency for the fresh water discharged from the watershed to follow the Virginia shore more closely than the Maryland shore.

Oysters do not grow in fresh water. Although they sometimes can withstand rather long exposures to fresh water, they need salt in the water surrounding them to feed, grow, reproduce, and carry on other life processes. Oysters occurring near the head of the salt-water section of the river exist under difficult conditions. It will be pointed out later that growth in this region is frequently very slow and reproduction or setting often unsuccessful.

STREAM FLOW

Salinity of the Potomac is influenced chiefly by the rate of discharge of fresh water from the drainage basin into the estuary, and this in turn is dependent on precipitation. Based on the 32-year period, 1897 through 1928 (47), the average annual precipitation for the watershed above Great Falls Maryland, was 39.81 inches and the average runoff 13.70 inches. Maximum stream flow occurs in March, but maximum precipitation occurs in June (see figure 6). The apparent discrepancy can be accounted for by reservoir-effects of snow and ice, imperviousness of frozen and saturated ground, storage in vegetation in summer and other factors. After a maximum stream flow in spring, the amount of water declines gradually through the month of September, then increases again as the reservoir capacity of the watershed changes.

Average conditions of stream flow have little effect on the oysters, but floods can occasionally kill those in the upper beds. Concerning floods in the Potomac, Somervell stated (47:4-5): "The Potomac watershed lies in a region of comparatively high rainfall and on two of the paths commonly followed by great cyclonic storms. Much of the area is mountainous or hilly with steep slopes and thin soil, conditions which are favorable to rapid concentration of runoff. As a result, floods are frequent. They ordinarily occur during the period from February to May, inclusive, but records show that the river has been above flood stage at Great Falls at least once during every month except July. These floods are of a flash nature and subside in from one to three days ... In spite of the large flood discharge, flood damage

Figure 6.-- Average yearly cycle of temperature, rainfall, and run-off for Potomac River watershed above Great Falls, Md., 1887-1929 (after Fig. II-3, Somervell, 1934).

is relatively small. The valleys of the basin are generally narrow and have but little bottom land. Much of this land is flooded so frequently that it is undeveloped."

In 1932, the U. S. Army Engineers (47) estimated that only once in a thousand years would a flood of from 475,000-530,000 sec. ft. be expected at Great Falls, Maryland, and once in a hundred years a flood of 375,000-425,000 sec. ft. Four of the 10 greatest floods in the Potomac, however, occurred within the recent six-year period 1936 through 1942; and of these four, one was of the magnitude of 1,000-year flood and another of a 100-year flood. In the light of these recent floods , the estimate of the Army Engineers has been revised.

Probably more important than the peak discharge is the total volume of water discharged during a flood and the time of year at which the flood occurs. Fresh water, being less dense than salt water, has a tendency to flow at the surface of a brackish water estuary. If, therefore, a flood comes in the fall when brackish water extends far upstream it would be expected that there would be relatively little dilution of the brackish water and little consequent damage to the oyster population. Table 2 shows that in terms of total discharge for the 3 month period including the flood, the October floods of 1942 and 1937 are lowest on the list. Although the flood of October 1942 is third greatest in terms of peak discharge (table 1) the 1942-43 survey of the oyster bars showed very little mortality on the bars recent enough to be attributed to the flood conditions. The inference can be drawn that peak discharge is not a suitable indication of possible damage to the oysters.

On the other hand, when floods occur in the spring or early summer, sometimes after long periods of high discharge, and at a time when the salt content of the river is low and the fresh-water-salt-water junction already quite far downstream, then, the oysters can be exposed to fresh water for relatively long periods and mortality can be severe. It has already been pointed out (p. 21) that the 1936 flood caused extensive mortality of oysters as far downstream as Cobb Island Bar. It seems likely on the basis of volume discharge, that the floods of 1902 and 1924 also caused mortality, although confirmation of this supposition is lacking.

Extremes of river discharge in the other direction, namely very low stream flow for long periods, affect the oyster populations by subjecting them to higher salinites than usual. It has long been believed by many oystermen that big sets of oysters usually occur in the driest years, 1930 being the outstanding example (13:22). The supposition in this case is that in the driest years the river discharge is lowest and the salinity consequently highest. So simple a relationship between setting and salinity, however, does not exist. In 1944, for example, salinity was quite high but setting very light.

TEMPERATURE

Temperature directly influences the rate of metabolism of oysters and other "cold-blooded" aquatic animals. At low water temperatures the various life processes, such as feeding, growth, reproduction, and respiration, are carried on more slowly than at higher temperatures. The oyster is commonly said to cease feeding at water temperature less the 4°C.

Table 1.--Greatest recorded floods of Potomac at Point of Rocks, Maryland

	Date	Discharge sec. ft.	Remarks	Source of data
1.	Mar. 19, 1936	480,000	peak	b
2.	June 2, 1889	460,000	estimated	f
3.	Oct. 16, 1942	418,000	peak	e
4.	Apr. 27, 1937	310,000	peak	c
5.	May 13, 1924	258,000	peak	a
6.	Mar. 2, 1902	212,000	daily mean	a
7.	Oct. 30, 1937	175,000	peak	d
8.	Feb. 24, 1897	173,000	daily mean	a
9.	Apr. 18, 1929	172,000	peak	a
10.	Mar. 31, 1924	160,000	peak	a

a. U. S. G. S. Water-supply Paper 771: 147-148.
b. " " " 800: 100.
c. " " " 821: 398.
d. " " " 851: 4-1.
e. Advance tabulation, U. S. G. S.
f. Bull. 1, Md. Dept. Geology, Mines and Water Resources, p. 89.

Table 2.--Total discharge of Potomac River at Point of Rocks, Md., for 3-month period at times of greatest floods, including month preceding, month following, and month of flood.

Date of Flood	Total discharge for 3 months in sec. ft. days x 10^6
Mar. 19, 1936	3.35
Mar. 2, 1902	3.14
May 13, 1924	2.36
Apr. 18, 1929	2.04
Feb. 24, 1897	1.97
Mar. 31, 1924	1.91
Apr. 27, 1937	1.75
Oct. 16, 1942	1.51
Oct. 30, 1937	1.31

Note:--There are no records for the flood of June 2, 1889, except the estimated peak discharge calculated from the rating curve of the 1936 flood.

Figures 7 and 8 indicate that from some time in December through some time in March, the water temperature in the Potomac is usually less than 4°C., although in mild winters it is likely that this cold water period is considerably shortened. Beginning in late March or April the water warms rapidly, reaching a peak in late July or early August. From late May through September, water temperatures are greater than 20°, and during most of June, July, and August they are higher than 25°C. Rapid cooling of the water occurs from late September through November.

The lowest recorded water temperature is minus 0.05°C. on January 15, 1920, at a depth of 37 feet at the mouth of the Potomac (52). On March 11-13, 1912, the entire river from Washington to the mouth had a temperature of less than 4°C., with many of the recorded temperatures less than 2°C. (50). The highest water temperature on record for the Potomac River region is a surface temperature of 31.3°C. on July 21, 1943, at Martin's Point Bar in the upper part of St. Mary's River. The bottom temperature at a depth of 13 feet at this time was 28.9°C.

The rapidity of temperature change at any place in the river is dependent on the ratio of the surface area to the volume of water present. In the upper part of the river there is a relatively small volume of water compared with the surface area; whereas, near the mouth of the river there is a large volume of water, the temperature of which is influenced by that of the huge reservoir of water in Chesapeake Bay. For this reason the water towards the head of the river warms up faster in spring and cools off more rapidly in fall than that near the mouth. This is illustrated by the two temperature regressions in figure 9 based on data from Stiles (49) which show that on April 15-16, 1913, during the warming period, water temperatures at Washington were considerably higher than at the mouth of the river, while on December 3-4, 1912, during the cooling period, they were markedly lower. Seasonal temperature curves for a number of localities along the length of tidewater would be similar in shape but the maxima would occur progressively later in the year towards the mouth of the river. Figure 7 indicates the type of shift or lag which would be expected. The temperature curve for 1920 at the mouth of the river shows a later warming in spring and cooling in fall than the curves of water temperatures at Indian Head in 1914 and Washington in 1882-1883.

Likewise because of surface-volume relationships the water towards the head of the river becomes warmer in summer and cooler in winter than that near the mouth of the river. This is demonstrated by the data collected by Ritter during the sanitary survey of the Potomac (44).

Usually, surface water temperatures are slightly greater than bottom water temperatures. On calm days in summer, steep micro-thermoclines can be detected at the surface, whereas, on windy days the water may be homothermal down to depths of 20 feet or more. Tidal currents prevent the development of a permanent summer stratification like that found commonly in fresh water lakes.

BIOLOGY

The biology of the Potomac River is almost unknown or, at least, is unpublished. The several sanitary surveys of the Potomac were concerned mainly with the bacterial content of water and oysters, although observations were

Figure 7.-- Annual cycle of water temperature in Potomac River. Curves for Indian Head in 1914 and the mouth of the river in 1920 show bottom temperatures, while that at Washington is for surface temperature.

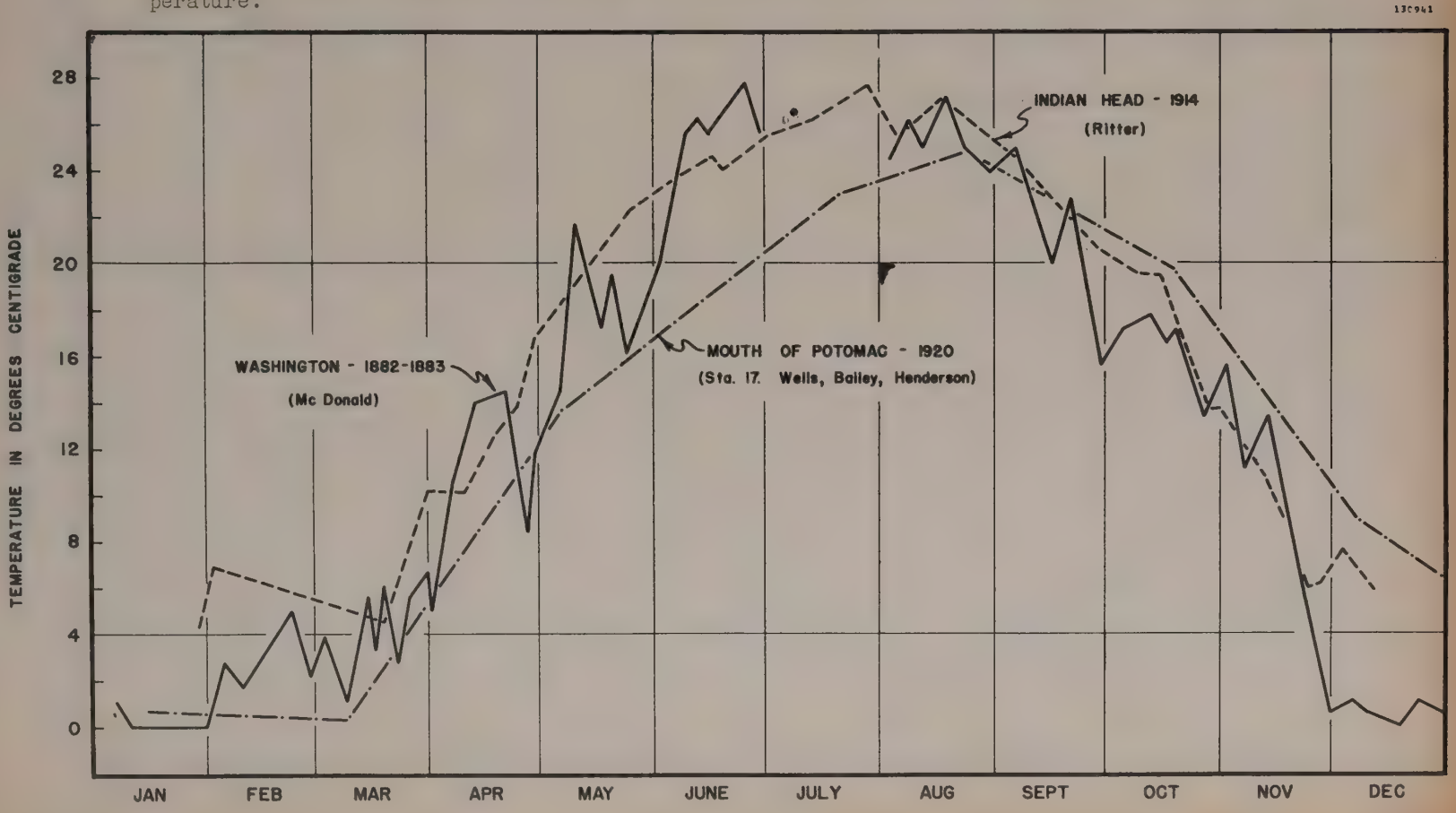


Figure 8.-- Cycle of Surface water temperature at St. Marys in St. Marys River during 1943-1944. Observations from September 1943 through May 1944 were made by biology class at St. Marys Seminary.

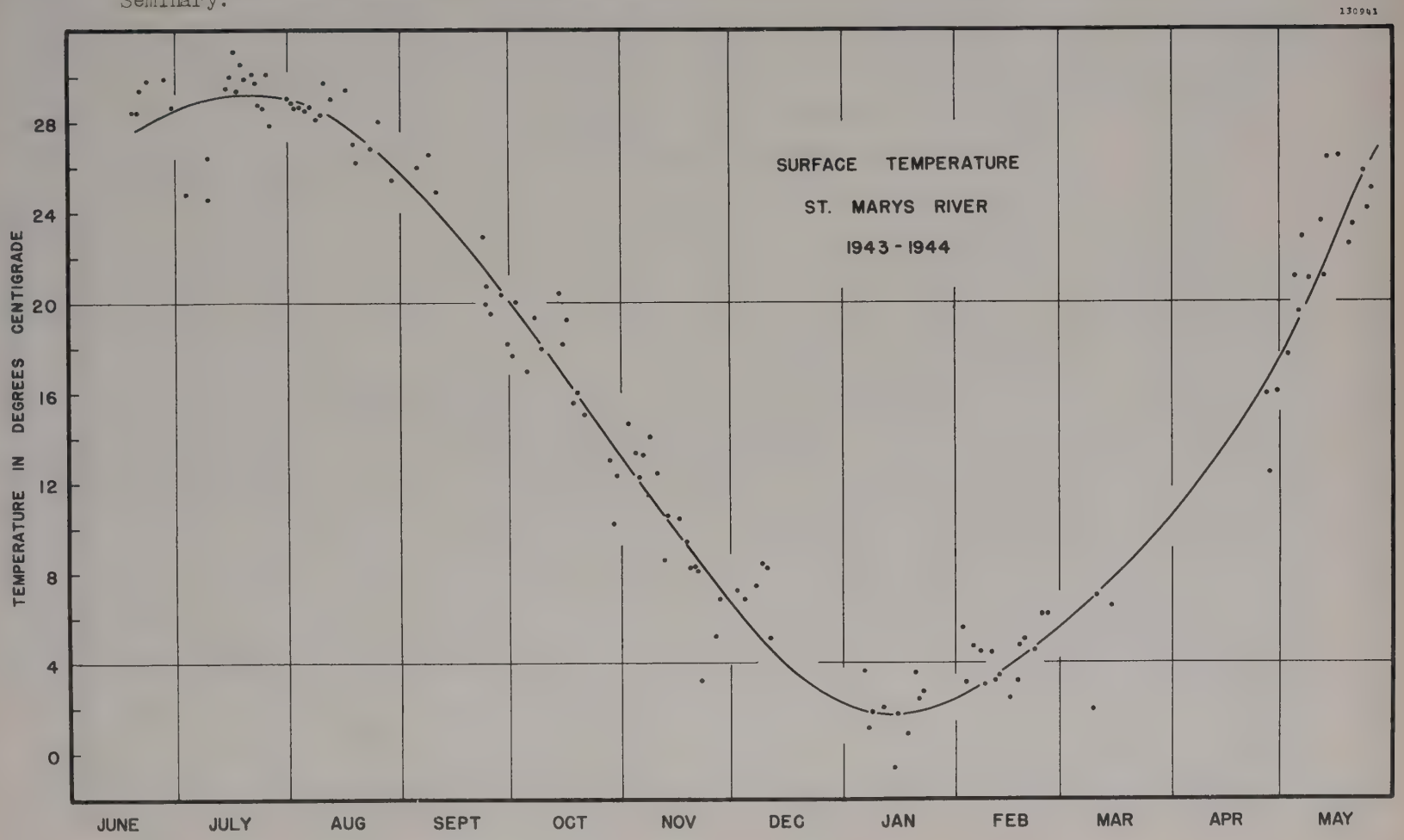
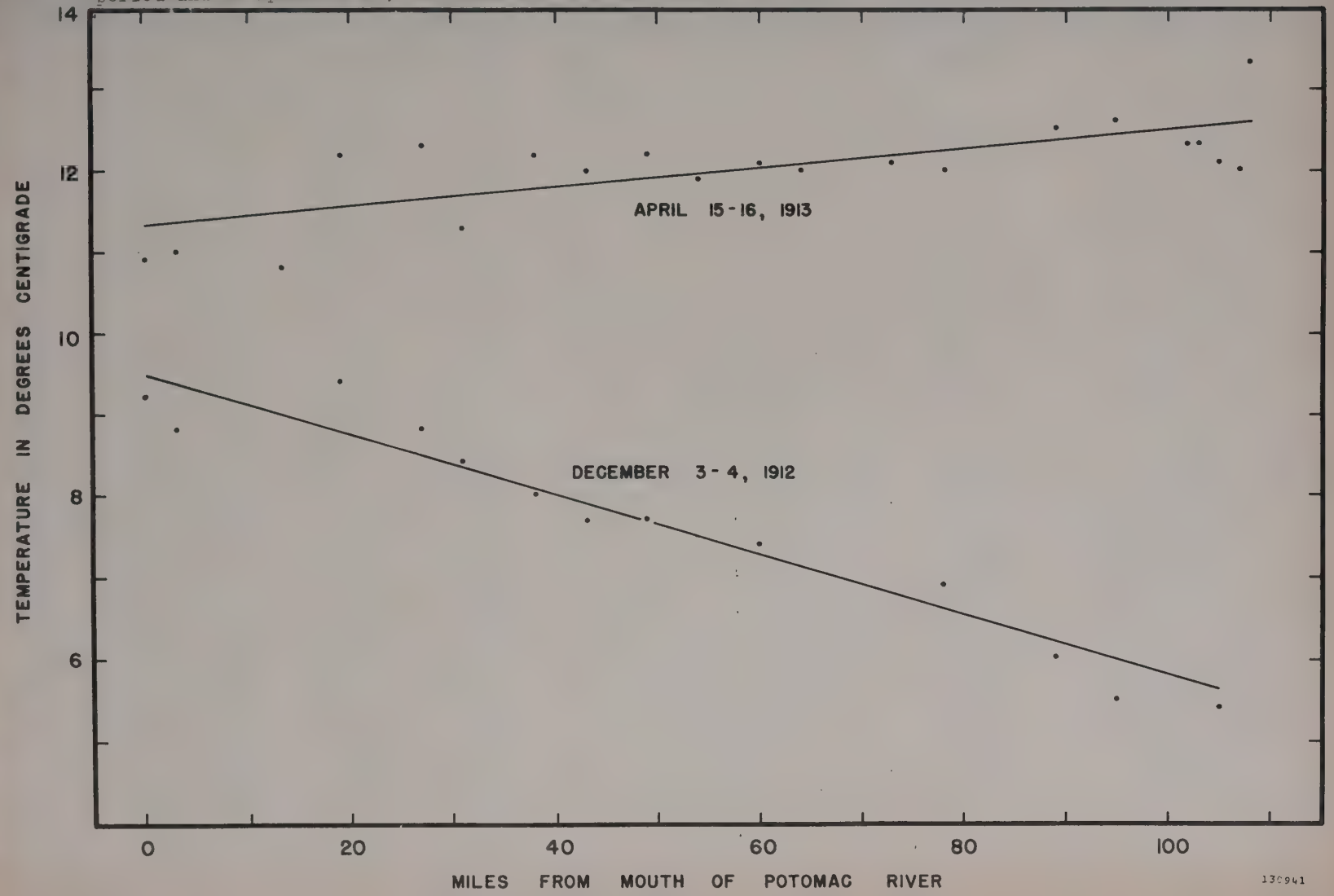


Figure 9.-- Profile curves of bottom temperature in Potomac River on December 3-4, 1912 during cooling period and on April 15-16, 1913 during warming period (Stiles).



also made on salinity, temperature, oxygen content, nitrate nitrogen, hydrogen ion concentration, and turbidity. Purdy in the most recent sanitary survey (36) contributed a chapter on the phytoplankton of the Potomac, with emphasis on the various diatoms present. Old (42) studied the distribution of boring sponge in the Potomac and its tributaries. Luce (40) surveyed the oyster bars of the lower Potomac and made observations on some of the animals associated with the oysters. The present study, in addition to presenting the results of the 1942-43 survey of the oyster bars, has attempted to summarize all material concerning conditions affecting the production of oysters in the river.

EQUIPMENT AND METHODS

The present investigation of the Potomac River oyster bars, as previously mentioned, was carried out during the period November 1942 to July 1943. For the survey, the Maryland Department of Tidewater Fisheries provided a 52-foot boat, the Sarah K, and crew of three. The boat was equipped with standard gasoline-powered winders, spool and pulley on the forward deck.

Three standard oyster dredges, each for use on a different type of bottom, were carried on the boat: (1) soft bottom dredge, 40 inches wide, equipped with 14 teeth, each 5 inches long, spaced an average distance of 3 inches; (2) hard-bottom dredge, 39 inches wide, equipped with 17 teeth each 2 inches long spaced an average distance of slightly more than 2 inches; (3) stone bottom dredge or scrape, 30 inches wide, equipped with an iron bar $2\frac{1}{2}$ inches by 3/4 inch, tapered to 1/8 inch along the contact edge. The bottom part of the bag of each dredge was made of 6 rows of iron rings $2\frac{1}{2}$ inches in diameter, each connected to adjacent rings by means of 6 two-inch figure-8 hooks. The remaining portion of the bags, of strong 1/4-inch cotton rope tied to form a net, varied in bar measure from 3 inches for the soft-bottom dredge to $2\frac{1}{2}$ inches for the hard-bottom dredge and $1\frac{1}{2}$ for the stone-bottom dredge. Type of bottom determined which dredge was used on a particular bar, and sometimes where bottom composition varied excessively different dredges were used on different parts of the same bar.

The general procudure in surveying an oyster bar was to drop numbered can buoys at intervals of 100 to 200 yards along the edge of the bar located by means of a sounding lead. At the corners of the bar and midway along sides exceeding one-half mile in length, flag buoys were anchored for reference points.

The $3\frac{1}{2}$ foot draft of the boat and the consequent danger of operating a dredge in shallow water made it inadvisable to extend the survey of the oyster bars into water less than 6 or 7 feet deep. For this reason an unknown acreage of oyster-producing bottoms comprising the shallow water portions of some of the bars was not examined.

After a bar had been outlined with buoys, the direction and distance between successive flags were determined by means of a taffrail log reading in statute miles, and the ship's compass. Positions of the intermediate buoys were approximated by noting the taffrail log reading when a line from the buoy was at right angles to the ship's course and by estimating the distance of the buoy from the ship's course. From these data a working outline of the bar was constructed at a scale of 3 mm to each 0.01 mile (1.5360).

Although this method of mapping was crude, numerous opportunities to check the results during actual dredging of the bars indicated that the maps were fairly satisfactory. Moreover, there was in general close agreement between the hydrographic data obtained during the survey and that shown on the Coast and Geodetic Survey charts. Facilities were not available for making a more exact survey.

Because it was found inconvenient to measure the length of each dredge haul by means of a taffrail log or a ground log it was finally decided to approximate this distance by multiplying together the elapsed time of dredging measured by stopwatch and the average speed of the boat. The latter was determined by ground log and stop watch to be 2.64 0.16 miles per hour (table 3). Knowing the width of the dredge, the area sampled by each dredge haul could then be readily calculated.

For reasons of subsequent analysis, it was desirable to make as large a number of dredge hauls on each bar as was practicable. Actually, an attempt was made to sample approximately one percent of the area of each bar. Each dredge haul was located in its proper position on the outline map of the bar and represented by a line drawn to scale in the direction the boat was heading. The hauls for each bar were numbered consecutively, and all data for each sample were recorded under the appropriate serial number.

For each dredge haul, duration of the haul in seconds, angle in degrees, and depth of water at the beginning and end were recorded. An attempt was made to adjust the duration of dredging so that the dredge would not be full. Duration of the hauls varied from 1/2 to 3 minutes, depending on the density of oysters and amount of shells or stones on the bottom. Large oysters (those 3 inches or more in length) were counted and their total volume measured; small oysters (those less than 3 inches in length) were counted and measured when abundant; spat (1942 oysters) and hinged shells (boxes) were counted; volumes of shells and stones were determined separately. All volume measurements were made in a straight-sided container of one standard bushel capacity, calibrated to tenths on the inner surface.

In the laboratory the counts and measurements of each dredge haul were converted to per-acre figures, and these were plotted on tracings of the maps in the positions of the corresponding dredge hauls. It was immediately apparent that the density of oysters was not uniform over the bars, but that various areas of concentration were present, depending on depth of water and other factors. Lines were then drawn by inspection, dividing each bar into a series of arbitrary isopopulation regions. Areas of the bars and of each isopopulation region were determined with a planimeter. Figures for the area of each region and for the average and total concentrations of large and small oysters in the region form the basis of the tables to follow.

DREDGE EFFICIENCY

It has been known for a long time that an oyster dredge does not catch everything in its path. Winslow in 1882 remarked (53:7-8): "From the information derived from experienced oystermen, and from our own examination of those beds that had been dragged, I was of the opinion that a dredge, when of considerable size, and dragged slowly, usually collected everything met by in its course ... (but) from the very small number of oysters to the

Table 3.--Observations on the speed of the boat during dredging observations. Distance traveled measured with a ground log.

Date	Bar	Haul No.	Time in seconds	Distance yds.	Yds. per sec.	Miles per hour
July 6, 1944	St. George	1	84	88	1.05	2.15
		2	47	82	1.74	3.56
		3	60	82	1.37	2.80
		4	95	77	0.81	1.66
		5	66	80.2	1.21	2.48
		6	77	87.3	1.13	2.31
		7	106	83.7	0.79	1.62
		8	58	87	1.50	3.07
		9	89	90.3	1.01	2.07
		10	70	87.7	1.25	2.56
July 7, 1943	Sheepshead	1	49	68	1.39	2.84
		2	49	75.3	1.54	3.15
		3	59	78.7	1.33	2.72
July 8, 1943	Huggins Pt.	1	39	66	1.69	3.46
		2	61	65	1.07	2.19
		3	46	80.7	1.75	3.58

Mean speed = 2.64 0.16 m.p.h.

square yard, as shown by the method, from the small number of oysters it assigns to the beds, and from comparison of the latter number with the number known to have been taken off the beds during our stay on the sounds, it is evident that the 'number to the square yard' given in the records of the work are usefull for comparison only; for in almost all cases the number of oysters given to the square yard must be considered as far below the real number ... consequently we must regard the 'number of oyster to the square yard' as shown by the method used, only valuable as establishing an initial number and standard by which the increase or decrease of oysters on the beds may be ascertained, and by which one bed or locality can be compared with another."

Stevenson also noted that the dredge is an inefficient sampling instrument for making quantitative studies of oyster populations (48:219). "The method by which information of this nature (number of oysters on the beds) has usually been obtained has been to dredge over the reefs and compare the number of oysters secured with the area over which the dredge has passed. It is not a satisfactory process ... and under no circumstances does the dredge catch all the oysters in its path."

Nevertheless, it was decided to use the dredge for sampling so that the results of the present examination would be comparable to those of the survey made by Luce in 1928. Realizing the inefficiency of the dredge, an attempt was made to work out a correction factor so that a better approximation of actual numbers of oysters could be obtained. Dredge hauls were made on 2 different oyster bars in the usual manner except that a buoy was anchored at the beginning and end of each haul and the distance dredged was accurately measured with a ground log. At 4 to 6 locations on either side of each dredging line a square reference frame measuring 1 yard along each side was dropped from the boat and with the aid of a diving helmet all oysters and shells within the frame were hauled to the surface for counting and measuring. Results of these observations are summarized in table 4.

As expected, the population figures determined from a dredge haul were in all instances, except two, considerably lower than corresponding population estimates made by means of the reference frame. This discrepancy was especially great in the case of small oysters and shells, where differences between the two sets of figures were usually at least 10-fold and in one instance as great as 170-fold. Differences between figures for marketable oysters were not so great except for haul No. 3 on Sheepshead and haul No. 3 on Huggins Point bar, at both of which locations the oysters were imbedded in the bottom, making it easy for the dredge to bounce over the oysters without catching them. Although moderately large quantities of shells were present on the bottom at these various locations, much was buried in the bottom or covered with loose mud, making it unsuitable as cultch material.

Because the dredge efficiency varies not only with the skill of the operator and the type of dredge used, but also with the type of bottom, habit of growth of oysters, and their abundance, a single factor for correcting population estimates based on dredge hauls could not be derived. For this reason, all figures in the table are uncorrected, and it must be realized that actual populations on the various bars were probably considerably greater than those listed.

Hence, although the results of this survey do not give the actual numbers of oysters on the bottom at the time of the survey, they are useful in determ-

Table 4.--Comparison of numbers of oysters taken by dredge with mean numbers occurring within square yard reference frames

Bar	Dredge haul	No. square yard samples	Method of sampling	Per acre calculations: Marketable oysters	Small oysters	Boxes	Bushels shells	Depth	Type of bottom
Sheepshead	1	4	dredge	1577	3155	0	6.6	6	Hard sand and mud with cindery shells imbedded and lying on surface. Most oysters lying on surface.
			yd.² frame	1210	87120	0	634		
	3	6	dredge	795	538	114	0.4	11	Soft layer of mud on top of hard sand and mud. Oysters partly imbedded in bottom.
			yd.² frame	8873	0	2420	68		
Huggins Pt	1	6	dredge	1219	6868	68	5.4	12-15	Hard and cindery. Oysters lying loose on bottom; not clustered.
			yd.² frame	6453	130680	807	260		
	2	6	dredge	1561	5781	0	6.9	12-15	Hard sandy mud with soft material on top. Some oysters imbedded.
			yd.² frame	3237	25813	1613	94		
	5	6	dredge	111	0	0	0	10-13	Sand with 1-2 inch layer soft muddy sand on top. Oysters imbedded in bottom.
			yd.² frame	1613	0	3227	6		

ining the relative improvement on the bars since 1928. The figures in the tables are also valid for indicating the distribution of population densities on the bars. Statistical test involving standard errors of the means (see tables for individual bars) show that the isopopulation areas as established on the various bars are significantly distinct from one another.

DESCRIPTION OF INDIVIDUAL BARS

The following 17 oyster bars were examined and will be discussed individually in order of listing:

A. Maryland side of river

1. Lower Cedar Point
2. Swan Point
3. Cobb Island
4. Sheepshead
5. Heron Island
6. Huggins Point
7. Poseys Bluff
8. Blake Creek
9. Herring Run
10. Piney Point
11. St. George
12. Cornfield Harbor

B. Virginia side of river

13. Old Farms
14. Wakefield
15. Kingcopsico Point
16. Coles Point
17. Ragged Point

1. Lower Cedar Point Bar (December 11-12, 1942)

The northwest and west edges of the bar are very sharply outlined by a steep dropoff into the river channel. Along the southeast edge the transition is gradual to a soft muddy bottom. Extending from Morgantown towards the beacon is a ridge, of which approximately 30 acres were too shallow to be surveyed.

Strong tidal currents sweep over the bar almost continuously, leaving the oysters free of mud and sand. Large mussels and barnacles were abundant. The crown of the bar is of a cindery nature, composed more of mussel shells and bits of barnacles than of oyster shells. The mussel shells have been much used as cultch material, forming a broad oyster, very pointed at the hinge end. Oysters in the shallow northeast portion of the bar were broad and thick; and those towards the beacon were larger than those nearer shore.

No 1942 spat were found in any of the 50 dredge hauls. A number of clean boxes indicated recent mortality, possibly a result of the flood in October 1942. In very few samples, however, did the number of these exceed 100 per acre.

2. Swan Point Bar (December 15, 1942, to January 22, 1943)

Swan Point is the largest and most complex bar surveyed. Within its boundaries are: several cindery areas, chiefly on 2 lumps along the outer edge, where small oysters were abundant; hard sandy areas in the northeast and southeast corners; an extensive stony area in the east central region; and a large area of soft mud alternating with small patches of oysters and

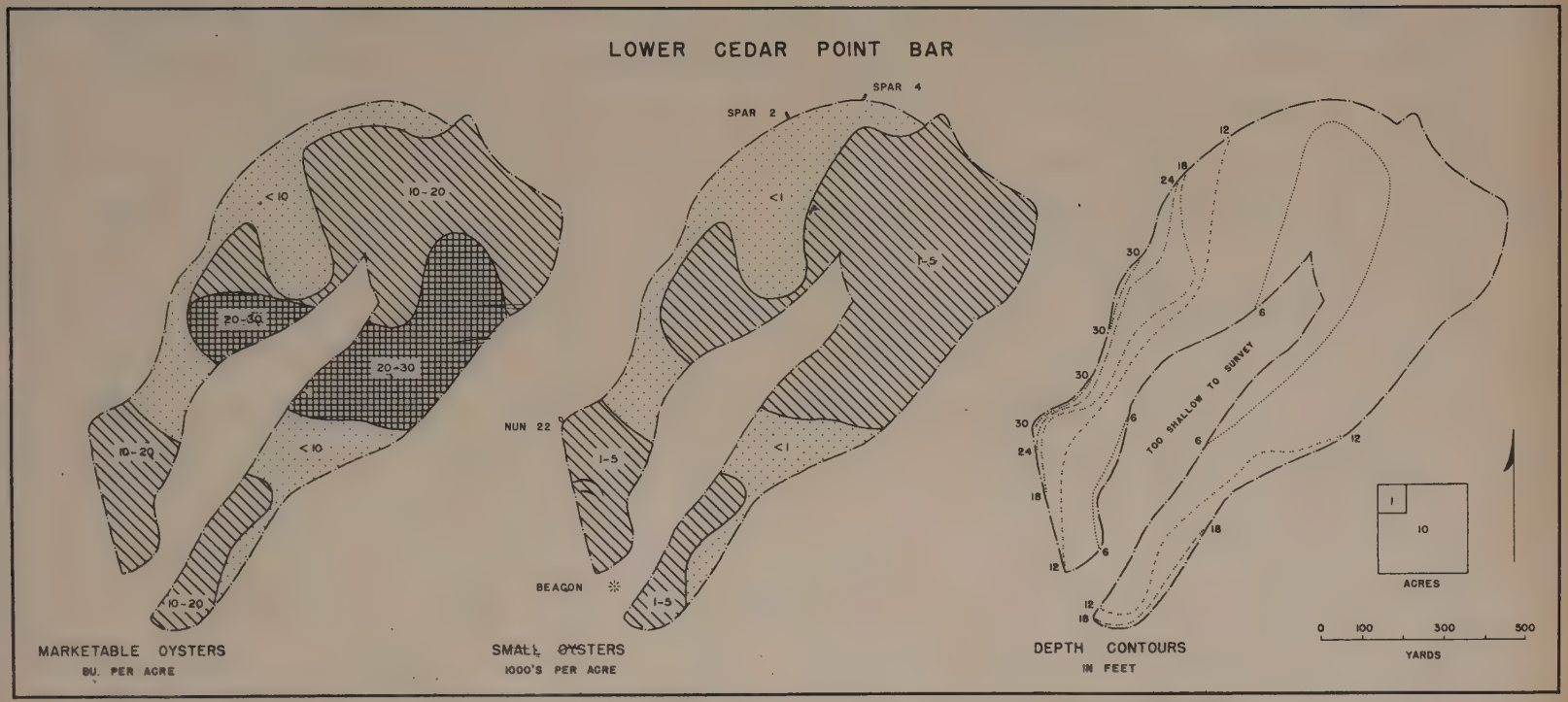


Figure 10.-- Isopopulation regions and hydrography of Lower Cedar Point Bar.

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Table 5.--Lower Cedar Point Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. of dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	<10 bu./acre	37.3	27.9	11	514 ± 74.3	19172	3.6 ± 0.74	134.3
and	10-20	65.2	48.7	25	1839 ± 76.9	119903	15.1 ± 0.54	984.5
larger	20-30	31.3	23.4	14	2917 ± 175.1	91302	21.5 ± 0.96	673.0
	Entire bar	133.8	100.0	50	1722	230377	13.4	1791.8
less than	<1000 /acre	47.5	35.5	16	353 ± 58.4	16768		
3"	1000-5000	86.3	64.5	34	2394 ± 124.5	206602		
	Entire bar	133.8	100.0	50	1669	223370		

shells ("broken bottom") in the northwest portion. Mussels and barnacles were abundant, and much of the cultch material in the cindery area was formed by the shells of these two organisms. Concentration of large oysters in the northern third of the bar were unaccompanied by comparable concentrations of small oysters indicating that this region of the bar is probably slowly losing its productivity. Many oysters on the bar were misshapen from growing around stones and mussels.

The southwest corner of the bar lies within the Dahlgren firing range and is subject to shelling. Twice dredge hauls in this region appeared to have entered shell holes, and on another occasion shells were actually observed to land on the bar, shooting a column of water and mud many feet into the air. Except on the portion of the bar immediately adjacent to the white spar, where fair concentrations of large and small oysters occur, it is likely that little damage results from the shelling.

The southwest corner of the bar lying within the firing range was heavily covered with loose "grass" (mainly Potomageton pectinatus), which perhaps had been carried downstream from the upper river and deposited there. No evidence was found that any of these plants were rooted in the bottom, although the plant is known to thrive in brackish water and was found growing abundantly farther downstream. At the time of dredging, it was often difficult to get to the bottom because of this mat of vegetation. One region at the southeast end of the bar and another towards the northeast corner contained no oysters at all.

The inequalities of distribution are striking. One quarter of the bar contained 80 percent of all the small oysters, while 31 percent of the area had more than half of all the marketable oysters. Fifty percent of the area contained fewer than 400 small oysters per acre.

Very few 1942 spat were found on the bar. A small amount of recent mortality, evidenced by clean shells still hinged, may have been caused by the flood of October 1942.

3. Cobb Island Bar (December 8-10, 1942)

Cobb Island when surveyed in 1942 was found to be in scarcely better condition than Luce reported in 1928. More than 80 percent of the area surveyed contained only 3 bushels of marketable oysters per acre, and almost 60 percent had fewer than 30 small oysters per acre. Along the sandy bar running from Cobb Island to the beacon there was an adequate covering of shells on the bottom but elsewhere only small quantities of cultch were present. The main concentrations of large and small oysters were found in shallow water near a stone pile, said to be ballast dumped there many years ago from a schooner.

Local oystermen claimed that the bottom of Cobb Bar changes with the weather; one week the bottom will be very hard and oysters hard to get; whereas, the next week, after warmer weather, fair amounts of oysters would be taken They suggested that plenty of oysters could be obtained with the stone dredge, but when used no more oysters were brought up with it than with the hard bottom dredge.

Figure 11.-- Isopopulation regions and hydrography of Swan Point Bar.

Table 6.--Swan Point Bar. Summary of results.

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
	0 bu./acre	30.6	4.1	9	0	0	0	0
3"	<10	242.9	32.9	59	459 ± 45.8	111421	3.8 ± 0.37	923.0
and	10-20	236.9	32.1	74	1770 ± 71.0	419313	14.2 ± 0.46	3364.0
larger	20-30	177.8	24.1	75	2719 ± 100.4	483438	22.4 ± 0.59	5982.7
	>30	50.9	6.9	23	4659 ± 334.8	237143	36.9 ± 1.43	1878.2
	Entire bar	739.1	100.1	238	1693	1251385	13.7	10147.9
	0 /acre	30.6	4.1	9	0	0		
less than 3"	<1000	369.2	50.0	107	331 ± 25.6	122205		
	1000-5000	145.9	19.7	53	2508 ± 169.7	365917		
	5000-10000	98.3	13.3	39	6708 ± 372.2	659396		
	>10000	95.1	12.9	30	13280 ± 614.7	1262928		
	Entire bar	739.1	100.0	238	3261	2410446		

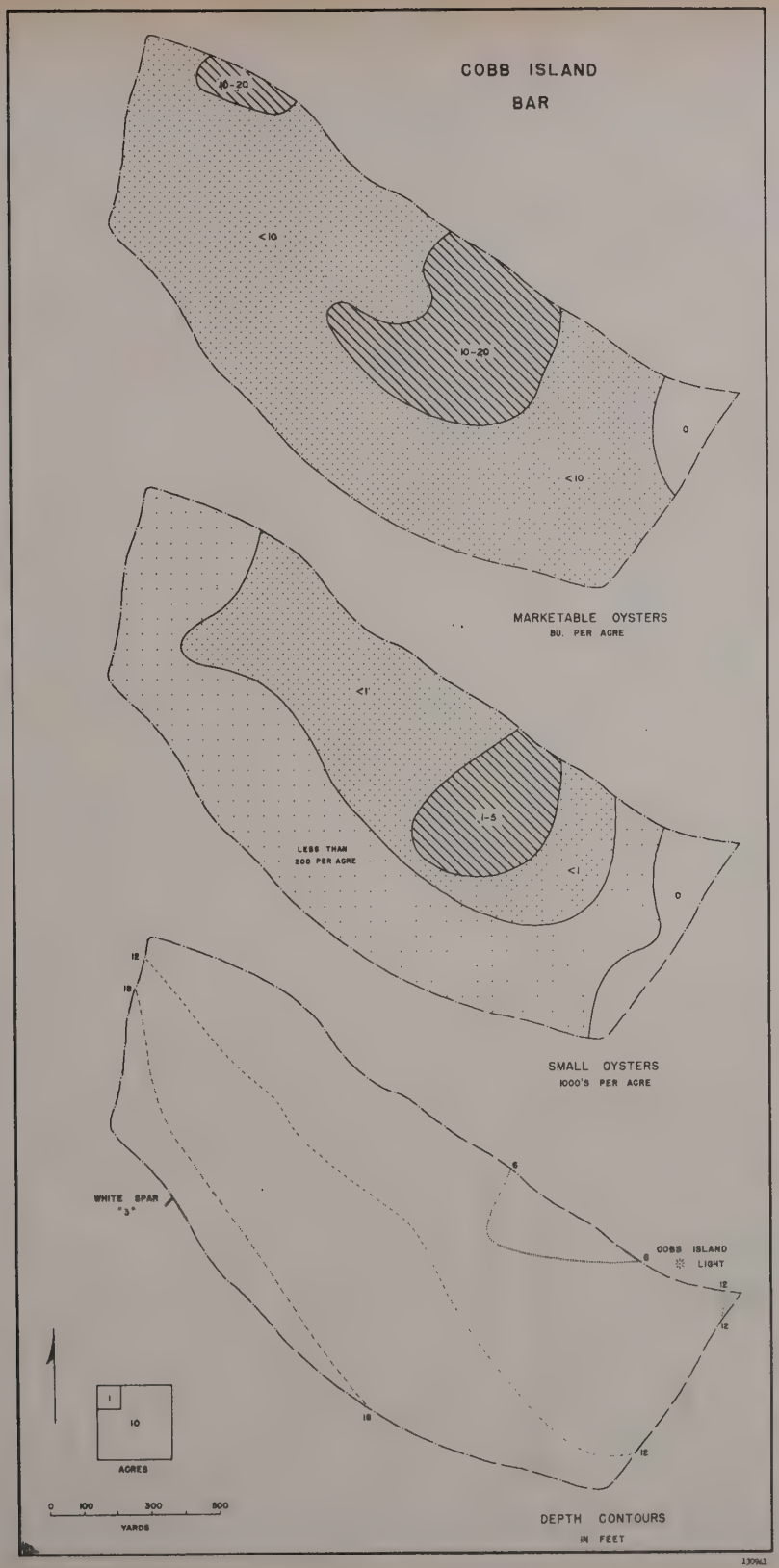

Figure 12.-- Isopopulation regions and hydrography of Cobb Island Bar.

Table 7.--Cobb Island Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bushels per acre	Total no. bushels in region
3"	0 bu. / acre	9.9	3.4	2	0	0	0	0
and	<10	232.0	78.9	56	405 ±59.2	93960	3.4 ±0.33	788.8
larger	10-20	52.1	17.7	11	1673 ±412.5	87163	11.9 ±0.75	620.0
	Entire bar	294.0	100.0	69	616	181123	4.8	1408.8
	0 / acre	16.8	5.7	5	0	0		
less than	<100	150.3	51.1	33	30 ±4.4	4509		
3"	100-1000	99.7	33.9	24	357 ±50.1	35595		
	1000-5000	27.2	9.3	7	2053 ±80.8	55298		
	Entire bar	294.0	100.0	69	324	95400		

Replenishment of the bar is very slow, as evidenced by the almost negligible numbers of small oysters found. Only 20 spat from 1942 were found in 69 dredge hauls. The marketable oysters even in December were very thin and watery. On December 8 many of these oysters still had enlarged gonads, which appeared to be active. As the water temperature at that time was less than 6°C., it is very unlikely that the oysters were able to resorb the gonad material and fatten before hibernation began.

4. Sheepshead Bar (December 1-18, 1942)

Extending northwestward from Blakistone Island is a broad shoal area which narrows to a shallow ridge near Black Spar "5" at the northwest corner of the area surveyed. Small oysters were abundant on the ridge and marketable oysters occurred at a density of 10 to 20 bushels per acre over most of the shoal. Except for a narrow region of concentration along the deep edge of the bar and a small area on the north side near Colton's Point, the rest of the bar contained fewer than 10 bushels marketable oysters per acre and fewer than 1,000 small oysters per acre. One area near the west end of the bar was found to contain no oysters at all, only large amounts of "grass." It is reported that Sheepshead Bar formerly extended considerably to the west of the region surveyed, as far as St. Catherine's Sound, but that within recent years portions of the bar have become sanded and covered with "grass".

It appears that the oyster population of the bar is barely maintaining itself. In addition to the barren area at the west, there is another at the extreme southeast corner where very few oysters were found. The small oysters occurred in 3 main concentrations: (1) on the ridge; (2) along the deep edge; and (3) opposite Dukehart's Channel between Blakistone Island and Colton's Point. Two of the regions, one on the ridge and the other opposite the Channel, comprised only 5 percent of the total area surveyed, yet contained 55 percent of all the small oysters found. Eighty-five percent of the small oysters occurred on 17 percent of the area of the bar.

Only 300 spat were found in the 119 dredge hauls and these were nearly all concentrated in the 3 regions previously mentioned, indicating that they are perhaps the only portions of the bar which receive an annual set large enough to replace population losses resulting from natural mortality and oystering. Dukehart's Channel or the "Swash" is reported to have a good catch of spat almost every year.

Most oysters outside these 3 regions were very large and well-shaped and evidently old. It is possible that many of them were derived from the good sets of 1930 and 1931. Fewer than 200 small oysters per acre were found in this entire region, comprising 75 percent of the total area.

Concentrations of shells were found on the ridge and opposite the Channel. Elsewhere, shells and other cultch material averaged less than 10 bushels per acre.

Hand tongers work almost entirely on the ridge and in the "Swash". Several patent tongers were working the concentration of large marketable oysters along the outer edge at the time of the survey.

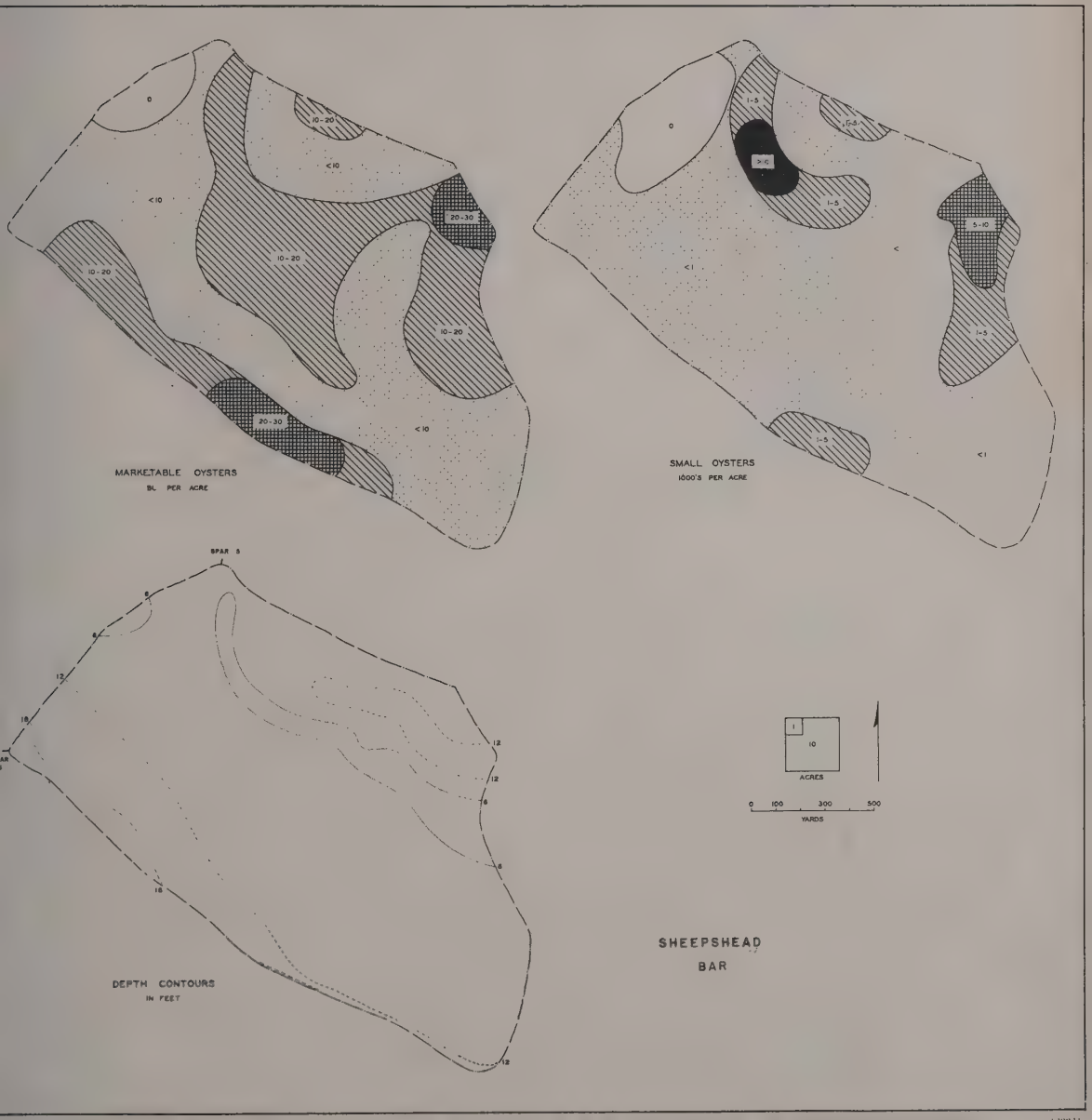

Figure 13.-- Isopopulation regions and hydrography of Sheepshead Bar.

Table 8.--Sheepshead Bar. Summary of results.

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	0 bu./acre	14.5	2.9	4	0	0	0	0
and	<10	277.2	55.7	61	577 ± 46.3	159944	4.1 ± 0.38	1136.5
larger	10-20	177.7	35.7	46	1919 ± 137.2	341006	14.0 ± 0.79	2487.8
	20-30	28.6	5.7	8	3817 ± 401.6	109166	25.0 ± 2.51	715.0
	Entire bar	498.0	100.0	119	1225	610116	8.7	4339.3
	0 /acre	33.9	6.8	9	0	0		
less than	<1000	374.3	75.2	82	167 ± 16.8	62508		
3"	1000-5000	63.6	12.8	20	2183 ± 277.1	138839		
	5000-10000	15.5	3.1	5	7102 ± 1297.1	110081		
	>10000	10.7	2.1	3	12859 ± 1088.8	137591		
	Entire bar	498.0	100.0	119	902	449019		

5. Heron Island Bar (November 19-20, 1942)

Of all the bars surveyed, Heron Island Bar averaged highest in bushels of marketable oysters per acre, but in contrast it had one of the lowest average concentrations of small oysters--450 per acre for the entire bar, and only 200 per acre on four-fifths of the bottom. Maximum concentrations of both marketable and small oysters coincided in deep water along the southwest side of the bar, almost due south of Heron Island. At this location 1942 spat also occurred in greatest concentrations.

Except in this one area there has been very little recent replenishment of the oyster supply on the bar. Most of the small oysters were only a little less than the legal size, 3 inches in length, and had thick shells indicating that they were several years old. The entire southern half of the bar contained an average of more than 400 boxes per acre, ranging to more than 1,000 per acre for several hauls. Mortality was not recent, as indicated by the presence of barnacles, bryozoa, and anemones on the inner surfaces of the hinged shells. These boxes constituted the major portion of all cultch material brought up by the dredge. Despite the fairly satisfactory quantities of large oysters present it appears that Heron Island Bar is doing little more than holding its own at present.

The north-central portion of the bar is stony, while the northwest corner is sandy and contains very few oysters. Large areas of the bar are reported to have been sanded during a violent storm in August 1933.

On December 21 and 22, 1942, the bar was dredged with the hard-bottom dredge for experimental purposes. Dredging on December 21 began at 1:45 and ended at 4:30 with 15 minutes off to adjust the dredge. In all, 30 heaping bushels (each roughly 1.2 standard grain bushels) of marketable oysters were caught. Assuming that the dredge was on the bottom 4/5 of the time, approximately 2.4 acres were dredged yielding 15.3 bushels per acre, or 14.4 bushels per hour of the time spent on the bar. On December 22, dredging began at 10:45 a.m. and ended at 1:05 p.m., by which time 20½ heaped bushels had been caught. Using the same assumptions in making the calculations, 2.2 acres were dredged, yielding 11.2 bushels of marketable oysters per acre or 10.6 bushels per hour of time on the bar. The region dredged was in the south half of the bar where large oysters were concentrated.

These results show that even when an attempt was made with a power boat and power-operated dredge to catch as many oysters as possible from the section of the bar with the greatest concentration of oysters, the number of bushels caught per acre of bottom dredged or per hour of working time was rather disappointing. The question is how long would the production of the bar continue at this level before declining to a point where it would be unprofitable to dredge the area. The decline in rate of catching from 15.3 bushels per acre on December 21 to 11.2 bushels per acre on Heron Bar 22 and from 14.4 to 10.6 bushels per hour working time might indicate that any original rate of removal would not be maintained for long under a program of intensive harvesting. Because this bar had the largest average concentration of marketable oysters of all the bars examined, it might be inferred that the others likewise would not maintain a high level of production under intensive dredging.

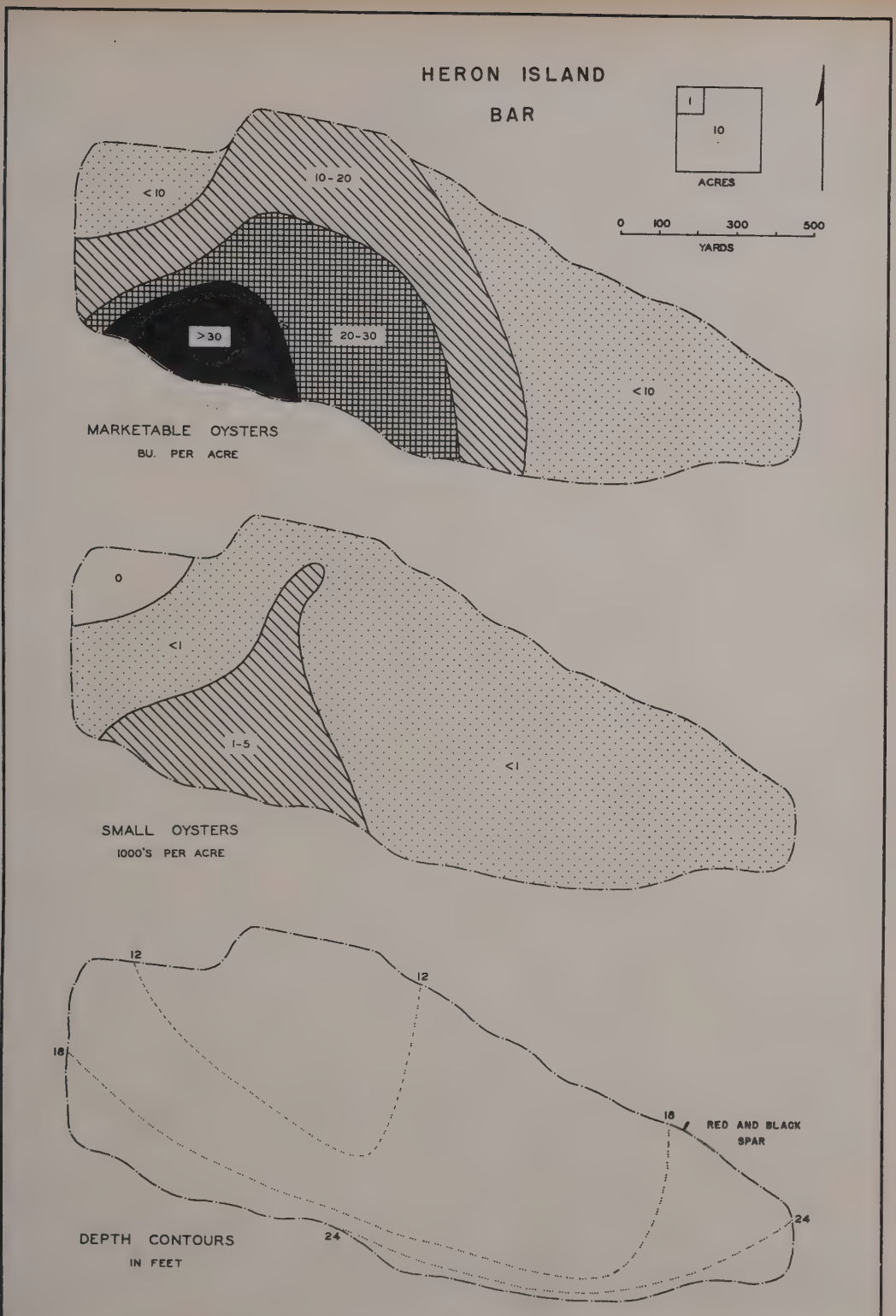

Figure 14.-- Isopopulation regions and hydrography of Heron Island Bar.

Table 9.--Heron Island Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	<10 bu./acre	86.0	39.9	16	546 ± 88.2	480+8	4.5±0.87	396.0
and	10-20	64.3	29.2	15	1556 ± 151.0	100051	13.4±0.87	861.6
larger	20-50	49.0	22.2	8	3191 ± 200.5	156559	25.6±0.93	1254.4
	>50	19.0	8.6	4	5114 ± 117.6	97166	37.2±1.25	706.8
	Entire bar	220.3	99.9	41	1825	401624	14.6	3218.8
	0 /acre	9.0	4.1	2	0	0		
less than	<1000	174.3	79.1	31	213 ± 34.6	37126		
3"	1000-5000	37.0	16.8	8	1672 ± 127.2	61864		
	Entire bar	220.3	100.0	41	449	98990		

6. Huggins Point Bar (January 25-26, 1943)

Huggins Point Bar was the first area examined in the present survey. Because of subsequent improvements in the method of surveying and because it was felt that the bar had not been adequately sampled, a second survey was made. All tabular material is based entirely on the second survey. Close agreement between the two surveys in distribution of isopopulation areas and quantities of oysters on the bottom demonstrates a reasonable accuracy in the methods employed.

East of a line from the beacon at the mouth of Breton Bay, there were few small oysters of marketable oysters except along the extreme outer edge of the bar. Population densities of both large and small oysters increased progressively towards the western edge where there occurred the greatest concentrations of small oysters found on any bar surveyed: 3 dredge hauls in this region showed an average of 41,370 small oysters per acre. In this general location a region comprising only 17 percent of the total area of the bar contained 82 percent of the small oysters found on the bar. More than 1,000 spat per acre were also found in this location. It is likely that these regions of high population density extended around the west side of the beacon into the county waters of Breton Bay.

The portion of the bar roughly corresponding to the isopopulation region of less than 10 bushels per acre had mostly a hard sandy bottom with a very sparse covering of shells. The rest of the bar had an average of 30 bushels of shells per acre, forming suitable cultch material for the attachment of spat.

In the south central part of the bar along the outer edge was a region of some extent containing more than 1,000 boxes per acre, which were nearly all large and not the result of recent mortality as indicated by the fouling organisms on their inner surfaces. Huggins Point and Heron Island were the only 2 bars showing such extensive mortality among the old oysters. The presence of so many old boxes still intact indicates that these two bars have not been extensively disturbed by tongs or scrapes in several years, otherwise the shells of many of the boxes would have been broken apart. Rather large numbers of boxes also were found on Piney Point, St. George and Cornfield Harbor bars, but these concentrations were more a mixture of various sizes than at Heron Island and Huggins Point.

7. Posey's Bluff Bar (November 30, 1942)

All concentrations of marketable oysters, small oysters, and spat occurred at depths of less than 12 feet. One region withing the 12-feet contour contained more than a thousand 1942 spat per acre. Very few small oysters were present on the bar, but this condition would be remedied within a year when the 1942 oysters are larger. Most of these spat were clustered and attached to stones along the inner third of the bar. Five tongers working inshore from the area surveyed reported large numbers of spat on the oysters they were catching.

Marketable oysters on Posey's Bluff Bar were large and fat, being in the best condition of all oysters examined from the river. The average density of 9.5 bushels per acre, however, probably indicates a population too small

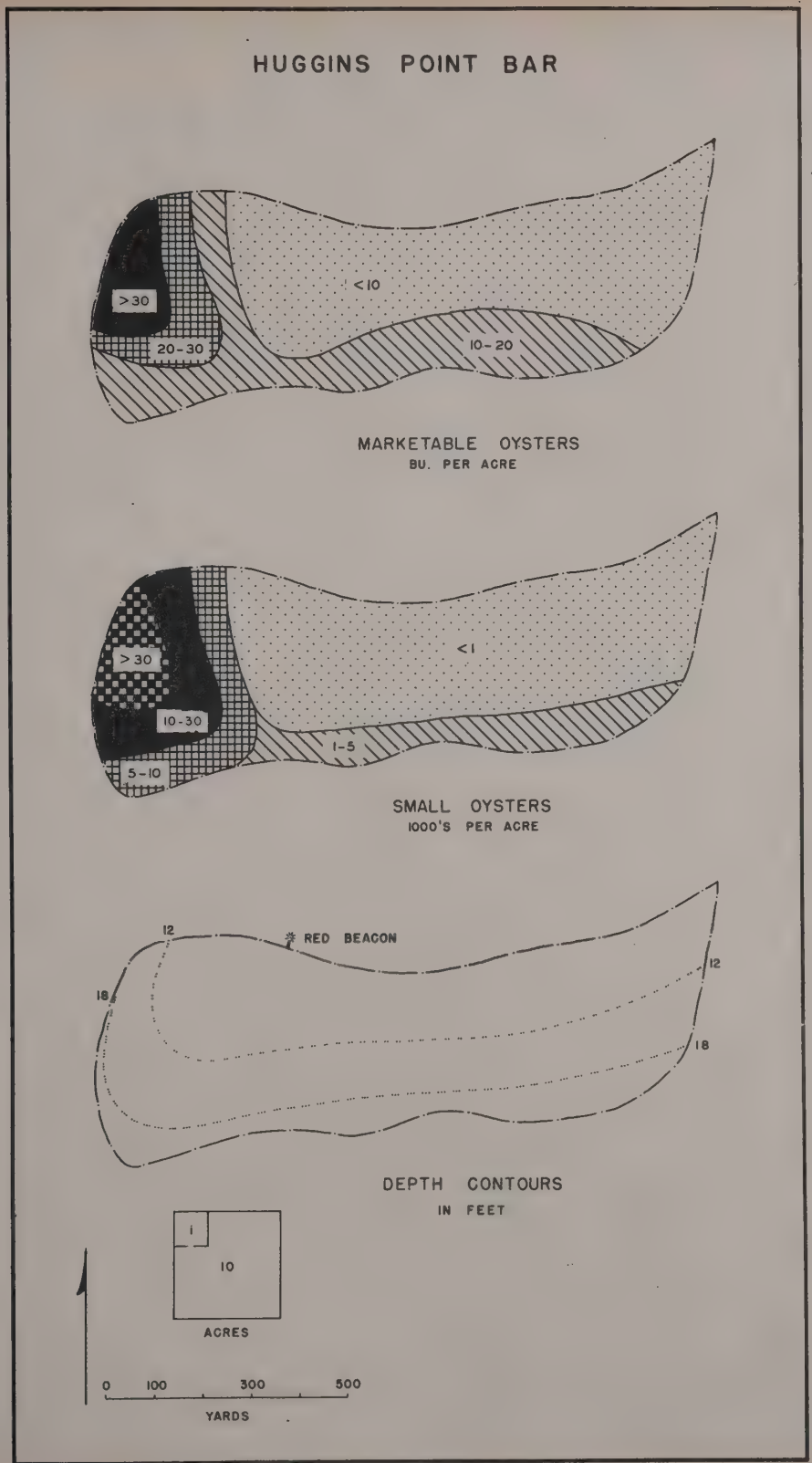

Figure 15.-- Isopopulation regions and hydrography of Huggins Point Bar.

Table 10.--Huggins Point Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
	<10 bu./acre	51.6	54.8	13	388 ± 94.7	20021	2.9± 0.73	149.6
3"	10-20	28.1	29.8	11	1763 ±122.3	49510	13.4± 1.01	376.5
and	20-30	8.1	8.6	4	3451 ±274.1	27953	21.1± 1.13	170.9
larger	>30	6.4	6.8	4	4212 ±104.0	26957	29.4± 1.76	188.2
	Entire bar	94.2	100.0	32	1321	124471	9.4	885.2
	<1000 /acre	56.1	59.6	15	298 ± 80.5	16718		
less than	1000-5000	12.7	13.5	4	1127 ± 84.2	14313		
3"	5000-10000	9.6	10.2	4	5457±1312.2	52387		
	10000-30000	9.9	10.5	6	13167±1710.9	130353		
	>30000	5.9	6.3	3	41570±2860.8	244083		
	Entire bar	94.2	100.1	32	4860	457854		

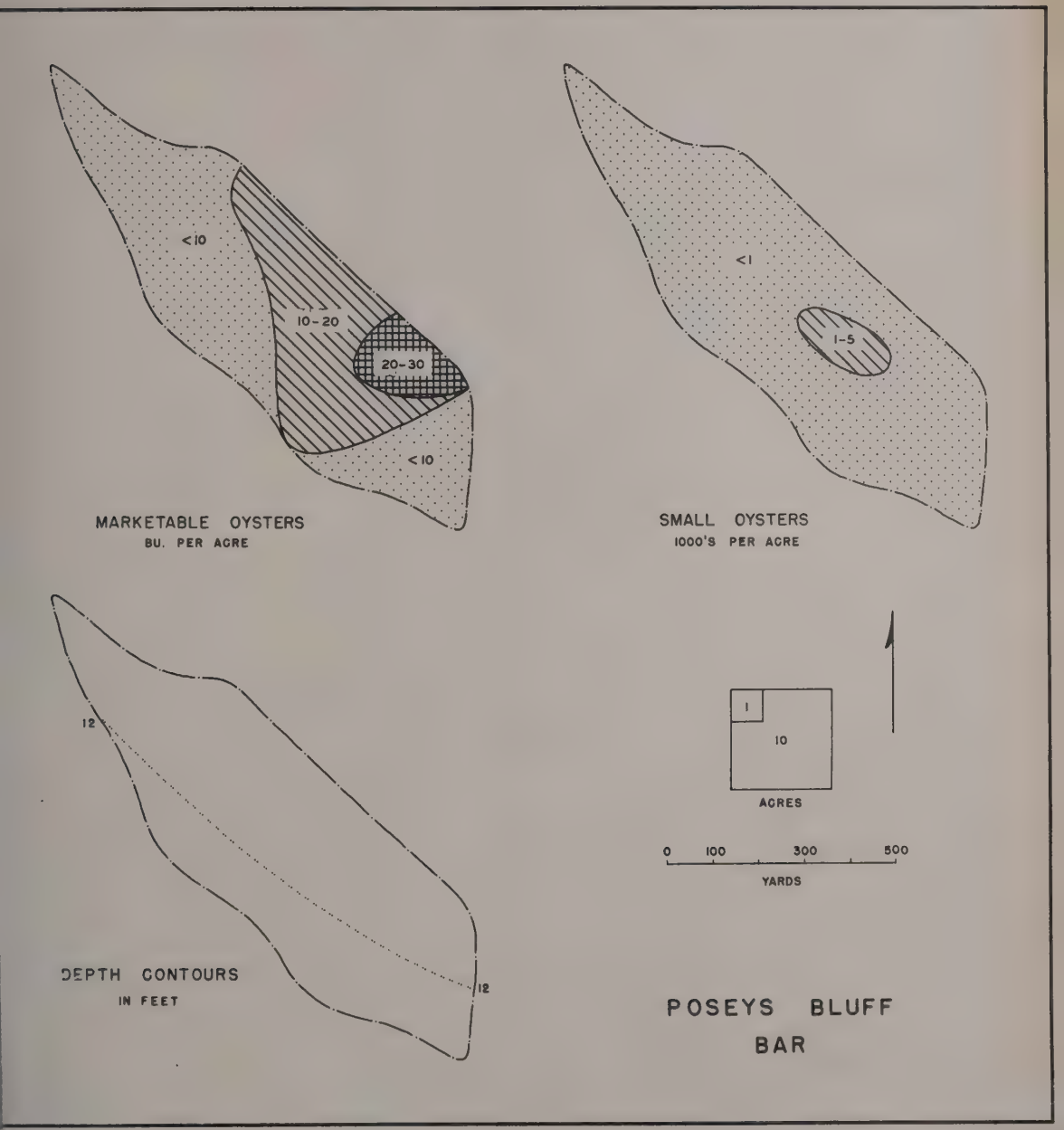

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Figure 16.-- Isopopulation regions and hydrography of Poseys Bluff Bar.

Table 11.--Poseys Bluff Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	<10 bu./acre	43.5	58.8	13	829 ± 70.5	36062	6.4 ± 0.83	278.4
and	10-20	24.5	33.1	6	1317 ± 117.1	32267	11.8 ± 0.71	289.1
larger	20-30	6.0	8.1	3	2786 ± 98.2	16716	22.3 ± 1.91	133.8
	Entire bar	74.0	100.0	22	1149	85045	9.5	701.3
less than	<1000 /acre	70.1	94.7	20	422 ± 38.5	29582		
3"	1000-5000	3.9	5.3	2	1103 ± 79.0	4302		
	Entire bar	74.0	100.0	22	458	33884		

to withstand intensive fishing.

8. Blake Creek Bar (November 27, 1942)

The 42-acre area surveyed was the poorest bar examined, containing an average of only 1.1 bushels of marketable oysters and 70 small oysters per acre. Although the bar was uniformly poor there were slightly greater population densities of both large and small oysters in the southeast quarter. Moderate numbers of spat (100 to 500 per acre) occurred along the inner edge of the bar. Very few shells were found on the bottom, which consisted almost entirely of hard mud and sand containing a scattering of stones.

From the inner edge of the surveyed area to the shore, approximately 200 to 300 yards away, the bottom appeared to be entirely hard sand. It would have been desirable to survey a portion of the bar in water shallower than 12 feet, but severe weather conditions prevented and it was not feasible to return to the bar later.

9. Herring Run Bar (November 12, 1942)

Considerable difficulty was experienced in finding this bar. When attempts to locate the bar by dragging a chain were unsuccessful because of the speed of the boat and the small concentration of oysters, three preliminary dredge hauls were made, the third showing a concentration of oysters sufficiently large to warrant surveying. An arbitrary area amounting to 22 acres was buoyed out and surveyed, rather than attempting to examine all the hard bottom, which was much greater in extent.

The entire area surveyed had more than 1,000 small oysters per acre, and the northeast corner contained 10-20 bushels of marketable oysters per acre. These latter oysters were large, well-shaped, and had very thick shells, indicating considerable age. Moderate numbers of spat from 1942 were observed.

Suitable cultch material appeared to be scarce. Stones, oysters, and shells were well separated on the hard sandy bottom, and nearly every solid object brought to the surface in the dredge had small oysters attached.

Herring Run was formerly a very large bar extending for several miles along the shore, according to local oystermen. Because of the difficulty in locating a portion of the bar containing even moderate numbers of oysters it seems likely that much of the bar has become sanded over and is no longer productive.

10. Piney Point Bar (June 23 and 30, 1943)

Beginning just below Piney Point the bar known locally as "Sea Oar Hollow Bar" extends as a narrow strip for approximately 1 mile along the shore. The character of the bottom changes from sand along the inshore edge to "broken" bottom along the offshore edge. At the upstream end of the bar the depth of water quickly increases to 18 feet, whereas the lower end of the bar extends onto the shallow flats above St. George narrows. In the latter location "grass" (Sea-oar or eel-grass, Zostera; widgeon-grass, Ruppia; sage pondweed, Potamogeton pectinatus) was growing abundantly.

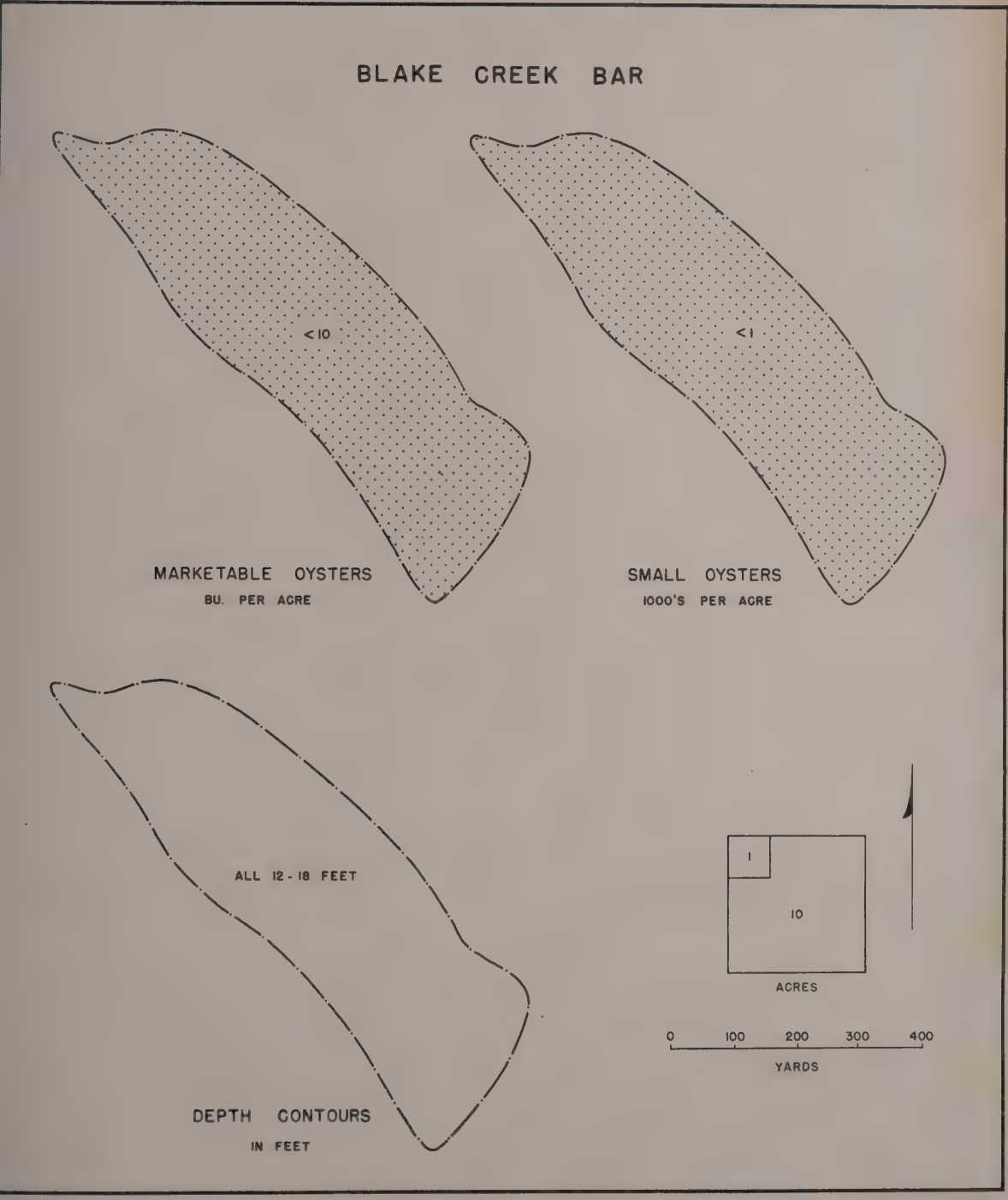

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Figure 17.-- Isopopulation regions and hydrography of Blake Creek Bar.

Table 12.--Blake Creek Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3" and larger	<10 bu./ acre (Entire bar)	42.4	100.0	10	171± 49.2	7250	1.1± 0.33	46.6
less than 3"	<1000/acre (Entire bar)	42.4	100.0	10	70± 52.2	2968		

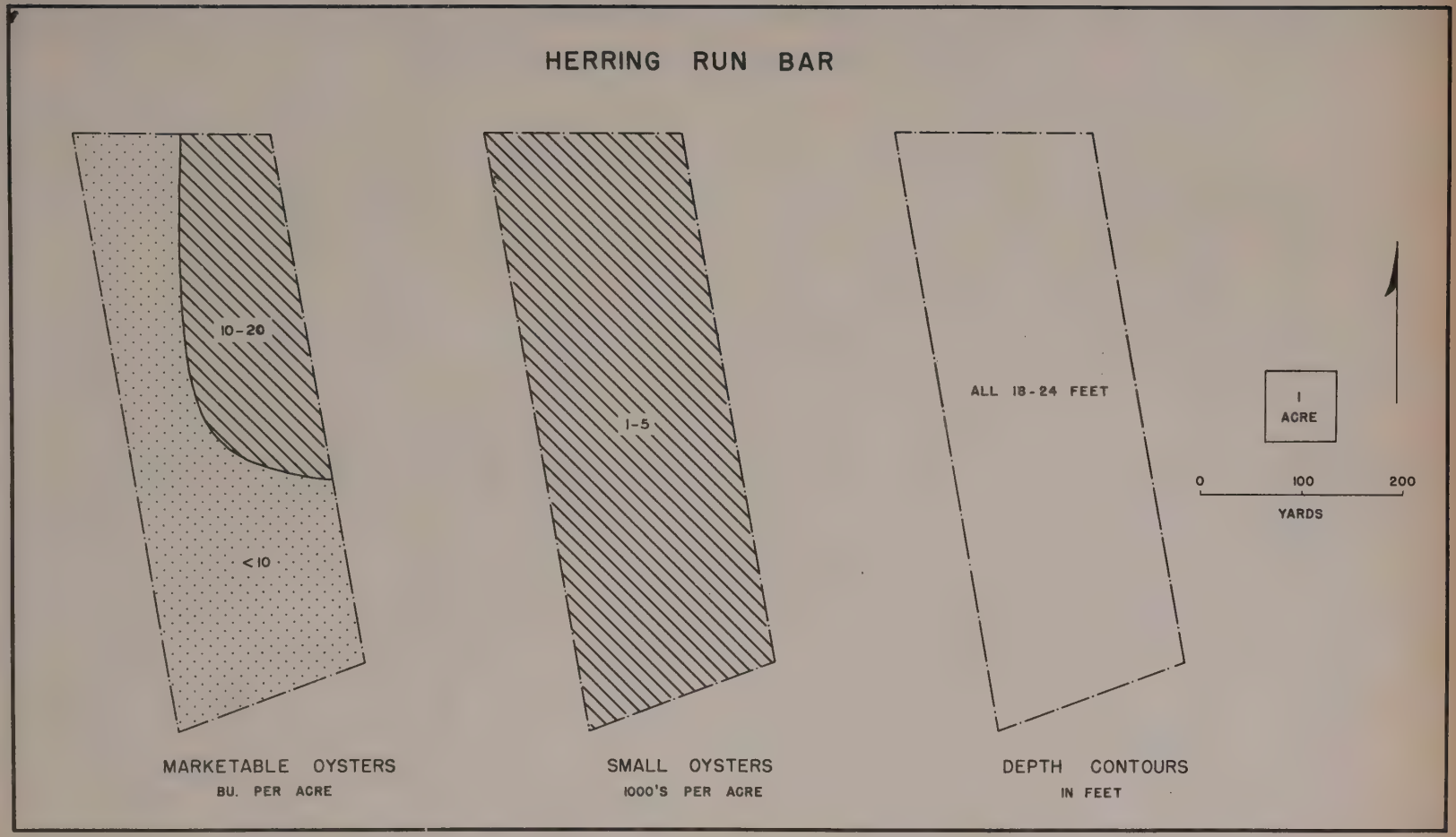


Figure 18.-- Isopopulation regions and hydrography of Herring Run Bar.

Table 13.--Herring Run Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	<10 bu./acre	14.9	67.1	5	936 ± 101.0	13946	5.9 ± 0.94	87.9
and	10-20	7.3	32.9	4	2095 ± 253.2	15291	14.7 ± 2.27	107.3
larger	Entire bar	22.2	100.0	9	1317	29240	8.8	195.2
less than 3"	1000-5000/acre (Entire bar)	22.2	100.0	9	1384 ± 166.1	30725		

Scarcity of cultch material combined with a good setting almost every year has resulted in the oysters growing in clusters. Small oysters were abundant over most of the bar. Spat from 1942 could be separated only with considerable difficulty from other small oysters, but there was certainly a heavy enough setting to provide replacement for all oysters removed by oystermen, assuming efficient culling. There was an average of more than 300 boxes per acre on the bar. Fouling organisms of various ages on the inner surfaces of these boxes and those on St. George and Cornfield Harbor bars indicated that this oyster mortality had not been recent, but rather had occurred over a number of years.

11. St. George Bar (June 24-30, 1943)

St. George Bar is a large bar extending most of the length of St. George Island from depths of 6 feet out to 18 feet or even more. The inshore half of the bar is mainly sand with a scattering of stones. Towards the outer edge of the bar "broken" bottom occurs. The lower outside edge of the bar is marked by a sharp dropoff to depths of more than 40 feet. The upper end of the bar extends almost to the channel dredged through the narrows of St. George Island. "Grass," consisting mainly of Zostera, was abundant towards the upper end and along the inshore edge of the northern half of the bar.

Cultch material was scarce on the bar, with the result that the oysters were densely clustered. An average of 550 boxes per acre was found in the 76 dredge hauls, representing the cumulative mortality of several years. No evidence of extensive recent mortality was observed.

Small oysters were fairly well distributed, and concentrated mostly in the southern half of the bar with the marketable oysters. On 21 acres midway along the inshore edge no marketable oysters were found, and on 8 acres in this same location there were no small oysters. Numbers of 1942 spat were generally distributed, but it was found impracticable to separate them from other small oysters. The presence of numerous age classes in the samples indicates that sets occur regularly.

12. Cornfield Harbor Bar (July 1-2, 1943)

Bottom composition on Cornfield Harbor Bar varied considerably. Most of the bar consisted of sand or muddy sand with occasional pockets of gray mud. The extreme upper end of the bar where no oysters were found was entirely mud. Quantities of stones were scattered over the southern half of the bar and along the inner edge of the northern half. In the latter location there also occurred masses of partially consolidated sand, reddish in color, known locally as "iron ore." Dredging was difficult and somewhat dangerous. Even with the stone bottom dredge a number of bad "hangs" were experienced.

Three areas of concentration of marketable oysters aggregating 41 percent of the total area of the bar contained 75 percent of all market oysters. In these areas, moderate concentrations of shells were observed, resulting mainly from an accumulation of more than 1,000 old boxes per acre. Over the entire bar boxes averaged 500 per acre. Stones likewise were most abundant in these 3 areas. More than half of all small oysters occurred in portions of two of these areas, comprising 21.5 percent of the total acreage of the bar. Frequency of setting and the relative scarcity of cultch material had resulted

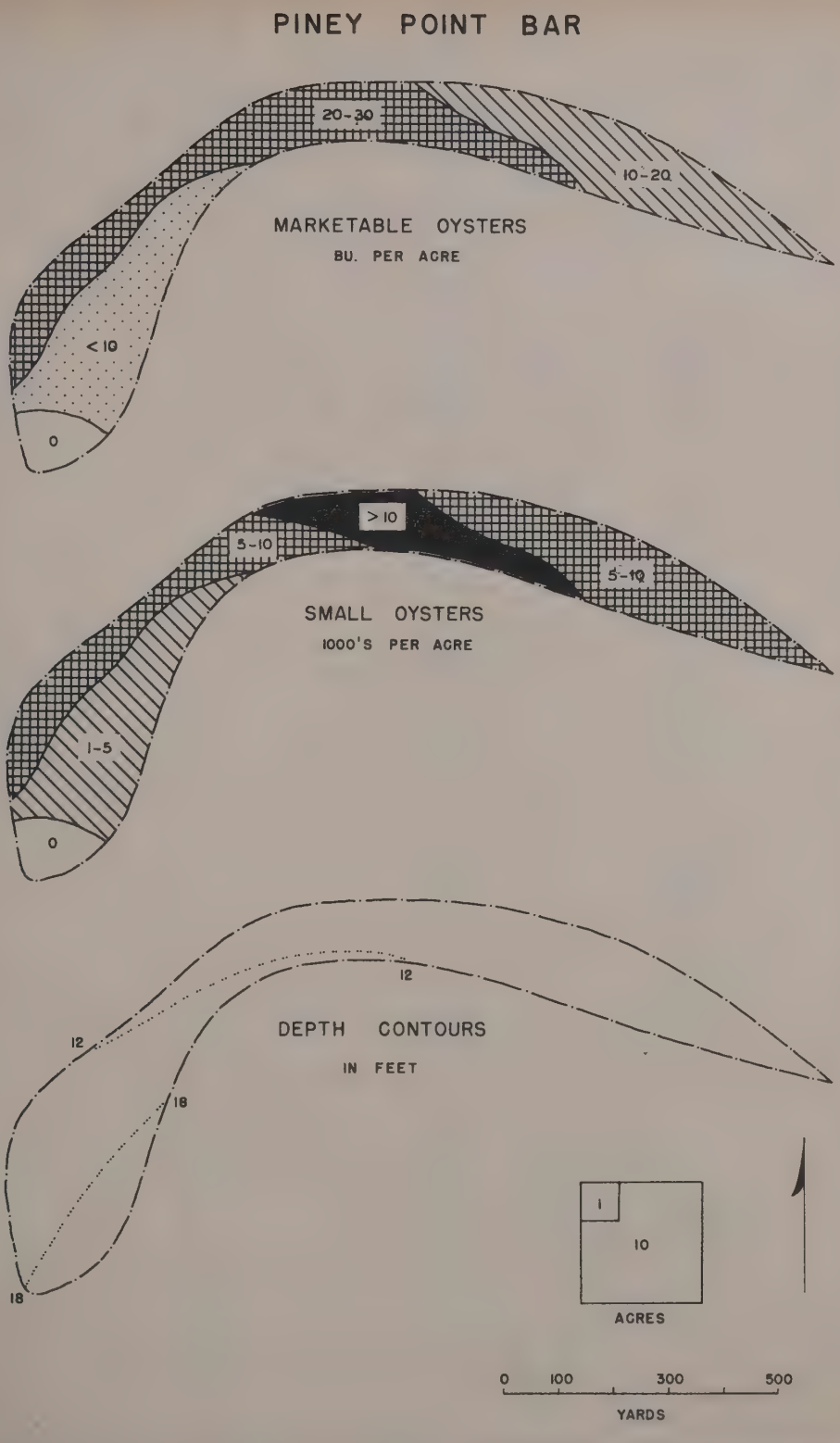


Figure 19.-- Isopopulation regions and hydrography of Piney Point Bar.

Table 14.--Piney Pt. Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
	0 bu./acre	2.6	5.3	1	0	0	0	0
3"	<10	13.8	28.0	7	792 ± 198.9	10930	5.4±1.45	74.5
and	10-20	14.4	29.2	6	2412 ± 208.7	34735	10.8±1.01	155.5
larger	20-30	18.5	37.5	9	4317 ± 457.4	79865	25.0±2.27	462.5
	Entire bar	49.3	100.0	23	2546	125528	14.0	692.5
	0 /acre	2.6	5.3	1	0	0		
less than	1000-5000	13.8	28.0	7	1697 ± 365.7	23419		
3"	5000-10000	25.1	50.9	11	6565 ± 666.9	164782		
	>10000	7.8	15.8	4	12406 ±1042.6	96767		
	Entire bar	49.3	100.0	23	5780	284968		

Figure 20.-- Isopopulation regions and hydrography of St. George Bar.

130941

Table 15.--St. George Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	0 bu./acre	20.6	5.1	4	0	0	0	0
and	<10	239.2	59.5	47	690 ± 66.8	165048	4.4 ± 0.44	1052.5
larger	10-20	142.4	35.4	23	1904 ± 95.0	271130	13.9 ± 0.71	1979.4
	Entire bar	402.2	100.0	74	1084	436178	7.5	3031.9
	0 /acre	8.5	2.1	2	0	0		
less than	<1000	68.0	16.9	15	420 ± 74.6	28560		
3"	1000-5000	238.9	59.4	44	2428 ±197.8	580049		
	5000-10000	87.0	21.6	12	5758 ±369.2	500946		
	Entire bar	402.2	100.0	74	2759	1109555		

in the oysters being clustered in the areas where concentrations were found. Spat from 1942 were moderately abundant among the clusters.

Because of the location of Cornfield Harbor Bar so close to Chesapeake Bay where dredging is permitted there is a great temptation for the large dredge boats of the Bay to work the bar. Law enforcement is difficult.

13. Old Farms Bar (February 2, 1943)

Old Farms Bar was characterized by the presence of large numbers of bent mussels (Brachidontes recurvus) which completely covered most of the marketable oysters. Many of the latter were twisted and misshapen from growing among the mussels. The majority of the small oysters, however, were free of mussels, indicating that there had been little reproduction among the mussel population for two or three years. Many marketable and small oysters were sharply pointed at the umbo end from growing on the inner surface of mussel shells. Except for small amounts of stones in the northeast quarter of the bar, mussels and mussel shells formed the bulk of available cultch material.

Marketable oysters averaged 5.5 bushels per acre for the entire bar, with no areas containing as many as 10 bushels per acre. Diagonally across the bar, however, was a narrow strip containing more than 1,000 marketable oysters per acre, with smaller numbers on either side. The isopopulation region of 1,000-5,000 small oysters per acre coincides roughly with the 12-foot contour shown on the U. S. Coast and Geodetic Survey Map 558. It would have been desirable to survey this entire isobath area, but time did not permit, and moreover, the outer portion extended into the firing range. Spat were entirely lacking in the 36 dredge hauls.

14. Wakefield Bar (February 3, 1943)

The portion of the bar surveyed lies approximately 400 yards off the mouth of Popes Creek. On the hard sand of the southeast side no oysters were found but elsewhere oysters were present. Concentrations of both large and small oysters occurred in the west central portion of the area. Here medium-sized stones were also abundant, making it difficult and somewhat dangerous to dredge the area. On several occasions the winders shook violently as the dredge contacted a particularly large stone. The outer edge of the bar in 15 to 18 feet of water had only a thin covering of shells and oysters, dark in color from lying on, or being partly imbedded in black mud.

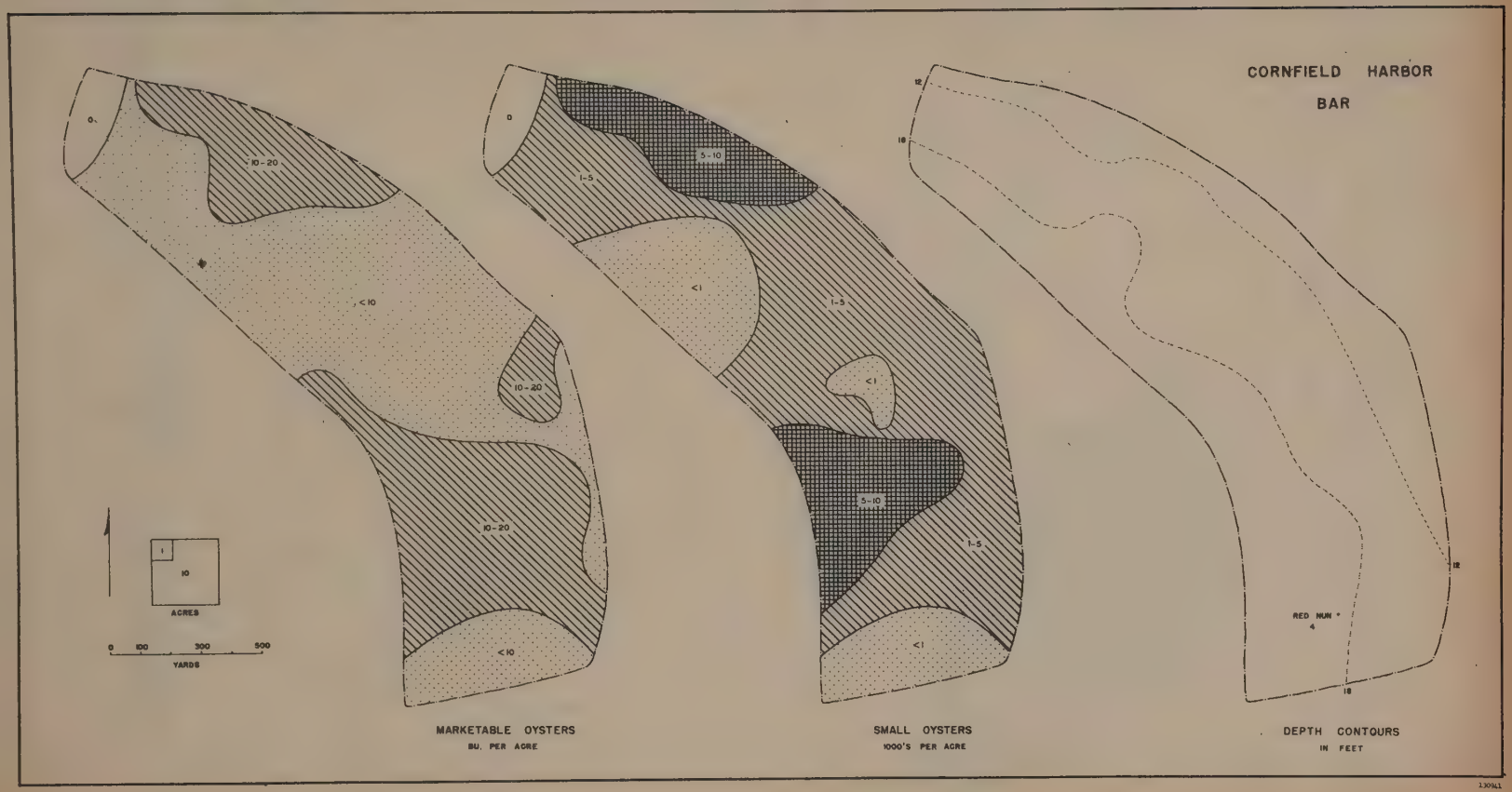
More mussels were found on Wakefield Bar than on any other bar examined, including Old Farms. Large oysters were so thickly covered that only 50 of them were needed to fill the bushel container. Hence, the bushel-per-acre figures used on the map and in the tables have been calculated from the counts of marketable oysters, assuming an average figure of 140 oysters per bushel. Mussels and mussel shells constituted nearly all the cultch material on the bar except for the stones previously mentioned. No 1942 spat were found.

Wakefield bar is considerably larger than the area surveyed, extending upstream for an additional thousand yards or more judging from Luce's survey in 1928. Time did not permit an extension of the survey to include the entire bar.

Table 16.--Cornfield Harbor Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	0 bu. / acre	9.3	2.7	2	0	0	0	0
and	<10	192.3	56.5	44	708 ± 64.5	136148	3.8 ± 0.37	730.7
larger	10-20	139.0	40.8	23	2630 ± 262.1	365570	15.0 ± 1.43	2085.0
	Entire bar	340.6	100.0	69	1475	501718	8.3	2815.7
	0 / acre	9.3	2.7	2	0	0		
	<1000	73.2	21.5	15	472 ± 66.2	34550		
less than	1000-5000	184.9	54.3	41	2361 ± 159.7	436549		
3"	5000-10000	73.2	21.5	11	8137 ± 1159.7	595628		
	Entire bar	340.6	100.0	69	3132	1066727		

Figure 21.-- Isopopulation regions and hydrography of Cornfield Harbor Bar.



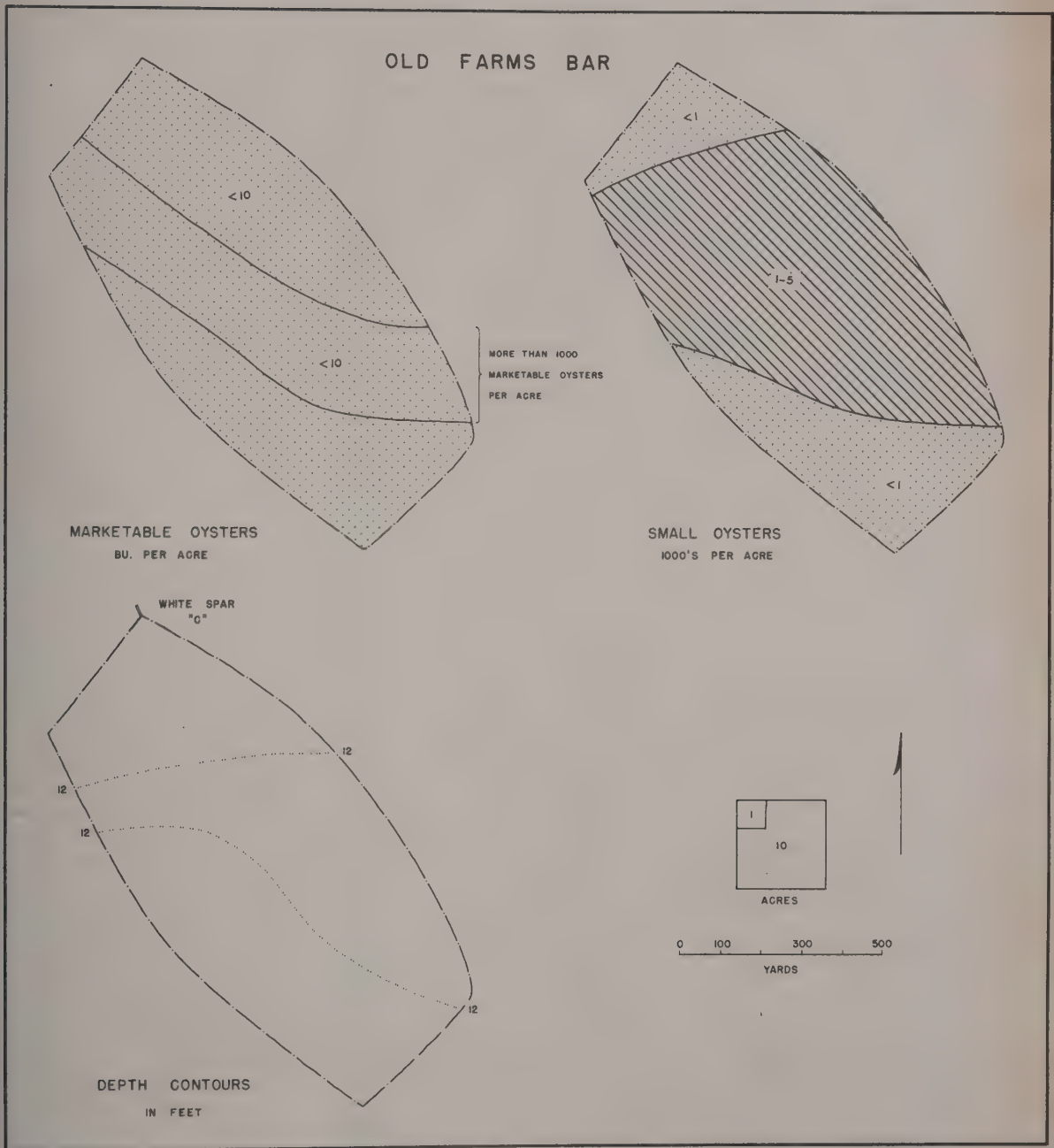


Figure 22.-- Isopopulation regions and hydrography of Old Farms Bar.

Table 17.--Old Farms Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3" and larger	<10 bu./acre (Entire bar)	133.0	100.0	36	820 ± 72.3	109060	5.5 ± 0.46	731.5
less than 3"	<1000/acre	45.3	34.1	13	385 ± 84.8	17421		
	1000-5000	87.7	65.9	23	2542 ± 303.5	222933		
	Entire bar	133.0	100.0	36	1807	240374		

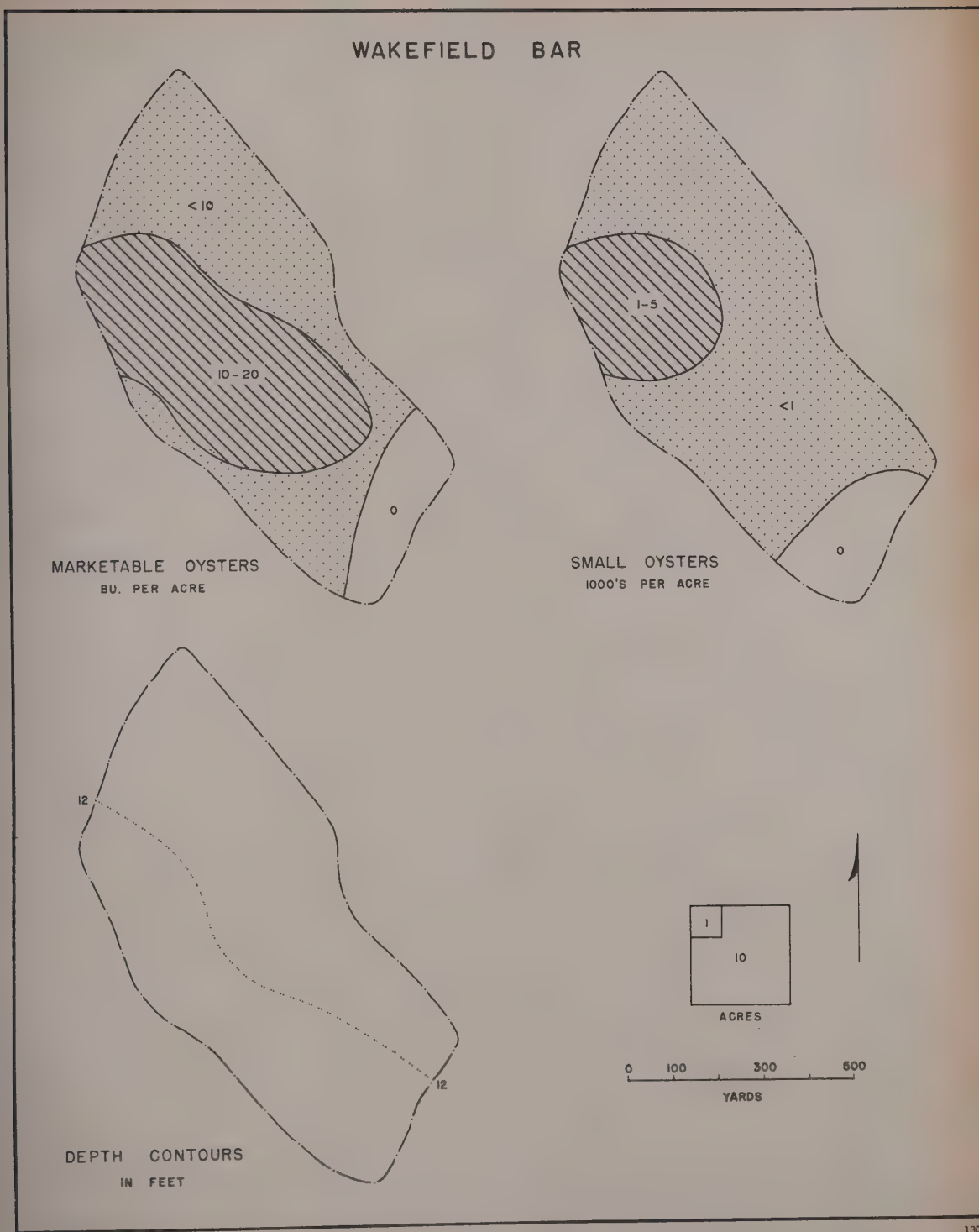


Figure 23.-- Isopopulation regions and hydrography of Wakefield Bar.

Table 18.--Wakefield Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	0 bu./ acre	10.6	10.4	3	0	0	0	0
and	<10	51.5	50.4	17	536±109.9	27604	5.8± 0.78	195.7
larger	10-20	40.1	39.2	12	1875±257.5	75107	13.4± 1.84	537.3
	Entire bar	102.2	100.0	32	1005	102711	7.2	733.0
	0 / acre	10.9	10.7	3	0	0		
less than	<1000	72.7	71.1	23	294± 57.4	21374		
3"	1000-5000	18.6	18.2	6	1902±602.9	35377		
	Entire bar	102.2	100.0	32	555	56751		

15. Kingcopsico Point Bar (November 16, 1942)

Kingcopsico Point Bar was surveyed only to the line separating county waters from State waters, although it was apparent that the oyster-producing area extended into the county waters of Nomini Bay.

Marketable oysters were most abundant along the stony inner edge of the bar, where concentrations of more than 10 bushels per acre were found. Outside this region, however, small oysters were most abundant, reaching a maximum concentration of 10,000 per acre in a region comprising 18 percent of the total area. Very few 1942 spat were observed. Handscraping would be more difficult in the stony region than elsewhere, which may account for the concentrations of marketable oysters along the inner half of the bar.

The narrow eastern tip of the bar had a meager covering of shells, but the remainder had an average of 40 bushels of shells per acre. The shells were mostly small, often broken and very clean, affording excellent cultch. Small oysters in the cindery areas were broad and well-formed. Along the muddy outer edge of the bar, shells were dark in color from being imbedded in the mud.

Most marketable oysters were just over 3 inches in length. This condition is designated by the oystermen as "straight up," meaning that at least 4/5 of the oysters are standards. Mussels although quite abundant on the bar were not a serious problem because they were mostly less than 1/2 inch in length.

16. Coles Point Bar (November 26, 1942)

Coles Point Bar is better known to the local oystermen by the name of "Stony Bar," an appropriate title. The area surveyed extended from Coles Point labeled on the U. S. Coast and Geodetic Survey map to the deep waters of Lower Machodoc Creek. Results of the survey indicate that the bar ends approximately on the line separating the county waters from the State waters.

The eastern half of the area surveyed was covered with many large stones, making dredging difficult. The western half of the bar had cindery bottom of small and broken shells, affording good cultch material. Largest concentrations of marketable oysters were found in the stony region where one area of 14 acres contained an average of 24 bushels per acre. Concentrations of small oysters were confined almost entirely to the half of the bar with a good covering of shells, where 80 percent of all the small oysters were found. Along the western edge the bottom was very muddy.

The bar extends into shallower water than could be surveyed by boat. On several occasions oystermen were observed picking oysters from the shallow water and even from the intertidal zone of the small island midway along the bar.

On the date of the survey, five boats were observed dredging for oysters on the bar, but as the survey boat approached they fled into Virginia County waters where they could not be apprehended by Maryland police.

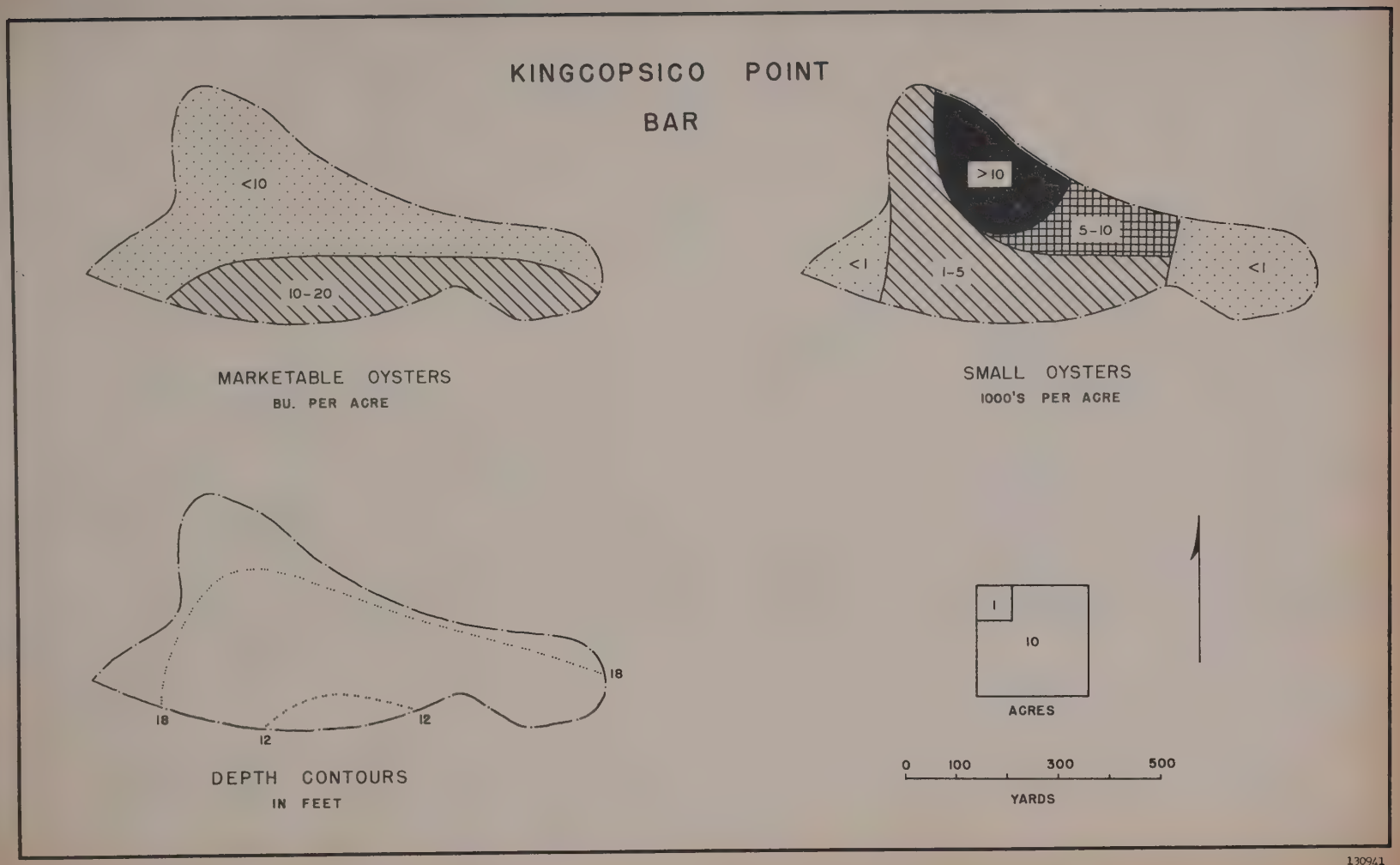


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Figure 24.-- Isopopulation regions and hydrography of Kingcopsico Point Bar.

Table 19.--Kingcopsico Point Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3" and larger	≤10 bu./ acre	32.5	65.8	10	809 ± 194.0	26293	2.7± 0.63	87.8
	10-30	16.9	34.2	5	2820 ± 631.8	47658	15.8± 2.59	267.0
	Entire bar	49.4	100.0	15	1497	73951	7.2	354.8
less than 3"	≤1000 / acre	12.5	25.3	5	196 ± 143.8	2450		
	1000-5000	21.4	43.3	5	2746 ± 450.9	58764		
	5000-10000	6.5	13.2	3	7118± 1053.2	46267		
	≥10000	9.0	18.3	3	9937 ± 415.9	89453		
	Entire bar	49.4	100.0	15	3986	196914		

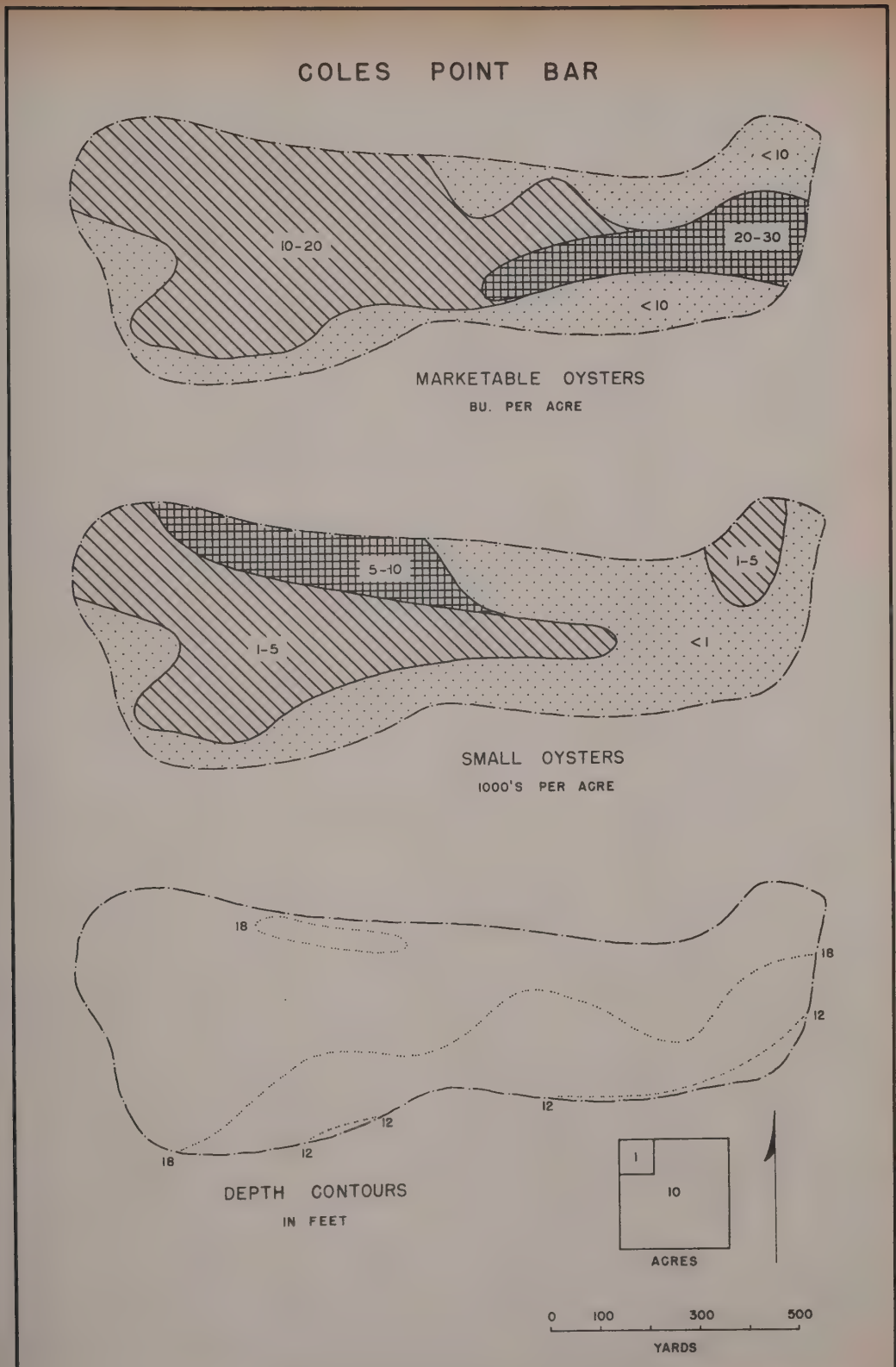

Figure 25.-- Isopopulation regions and hydrography of Coles Point Bar.

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Table 20.--Coles Point Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3"	<10 bu./ acre	31.9	27.9	10	960± 185.8	30624	3.9± 0.68	124.4
and	10-20	68.6	59.9	20	2393± 159.7	164160	13.0± 1.01	891.8
larger	20-30	14.0	12.2	4	3426± 240.7	47964	24.0± 1.33	336.0
	Entire bar	114.5	100.0	34	2120	242748	11.8	1352.2
	<1000/ acre	55.0	48.0	16	428 ± 78.1	23540		
less than	1000-5000	46.4	40.5	15	3156± 285.5	146438		
3"	5000-10000	13.1	11.4	3	5334± 133.7	69875		
	Entire bar	114.5	99.9	34	2095	239853		

Oysters in the stony region were heavily covered with 2-inch mussels and quantities of barnacles. Those from the shell area had fewer mussels of a much smaller size.

Only 43 spat from 1942 were found in the 34 dredge hauls, and these were mostly from the eastern stony half of the bar.

17. Ragged Point Bar (ove ber 17, 1942)

The portion of Ragged Point Bar surveyed was very sharply divided into 2 regions: the eastern half towards the light-house consisted of a loose-shell bottom on which there was an average of more than 10,000 small oysters per acre; the western half had a harder bottom with fewer shells, in which there were fewer than 600 small oysters per acre. Ninety-five percent of the small oysters were found in the eastern half of the bar.

Marketable oysters were moderately abundant but of small size that the bar averaged only 7 bushels per acre. No areas of concentration were detected by the survey.

Both marketable and small oysters were broad and well-shaped, especially in the eastern area. Mussels were quite common, although they were mostly less than 1/4 inch in length and were not objectionable. A good catch of 1942 spat was found in the eastern half of the bar.

Of all the bars surveyed, Ragged Point Bar had the highest average number of small oysters per acre, followed quite closely by Piney Point Bar. The large number of small oysters in the eastern half of the bar indicate that this area is maintaining itself better than is the western half. This was the best bar found on the Virginia side of the river. Local oystermen reported that productive oyster bottoms extend almost continuously from Ragged Point to Coles Point.

SUMMARY OF SURVEY

Table 22 summarizes the results of the surveys of the individual oyster bars. The quantity of marketable oysters on the various bars at the time of examination varied from a maximum of 14.6 bushels per acre for Heron Island Bar to a minimum of 1.1 for Blake Creek. Four bars on the Maryland side of the river and one on the Virginia side averaged more than 10 bushels per acre. The 12 bars along the Maryland shore averaged 2.3 bushels per acre more than the 5 bars along the Virginia shore, but contained fewer oysters per acre, indicating that marketable oysters on the Maryland bars were larger in size than those on the Virginia bars. This size difference is further demonstrated by the number of marketable oysters per bushel. On the Maryland bars it averaged 136 and for the Virginia bars 186, ranging from a minimum of 121 on Poseys Bluff to 291 per bushel on Ragged Point. Lower Cedar Point, Swan Point, Cobb Bar, Heron Island and Poseys Bluff bars had the largest oysters in the river. It might be expected as a result that it would be most profitable for handscrapers to work on these bars, and actually it was evident from reports and personal observation that Lower Cedar Point and Swan Point bars were preferred by handscrapers during the winters of 1942 and 1943. The smaller average size of marketable oysters on the Virginia side of the river may have resulted from the removal of a greater percentage of the large oysters by more intensive handscraping. Virginia has had fewer patrol boats than has Maryland which may indicate that handscraping, as a result, has been more prevalent along the Virginia shore.

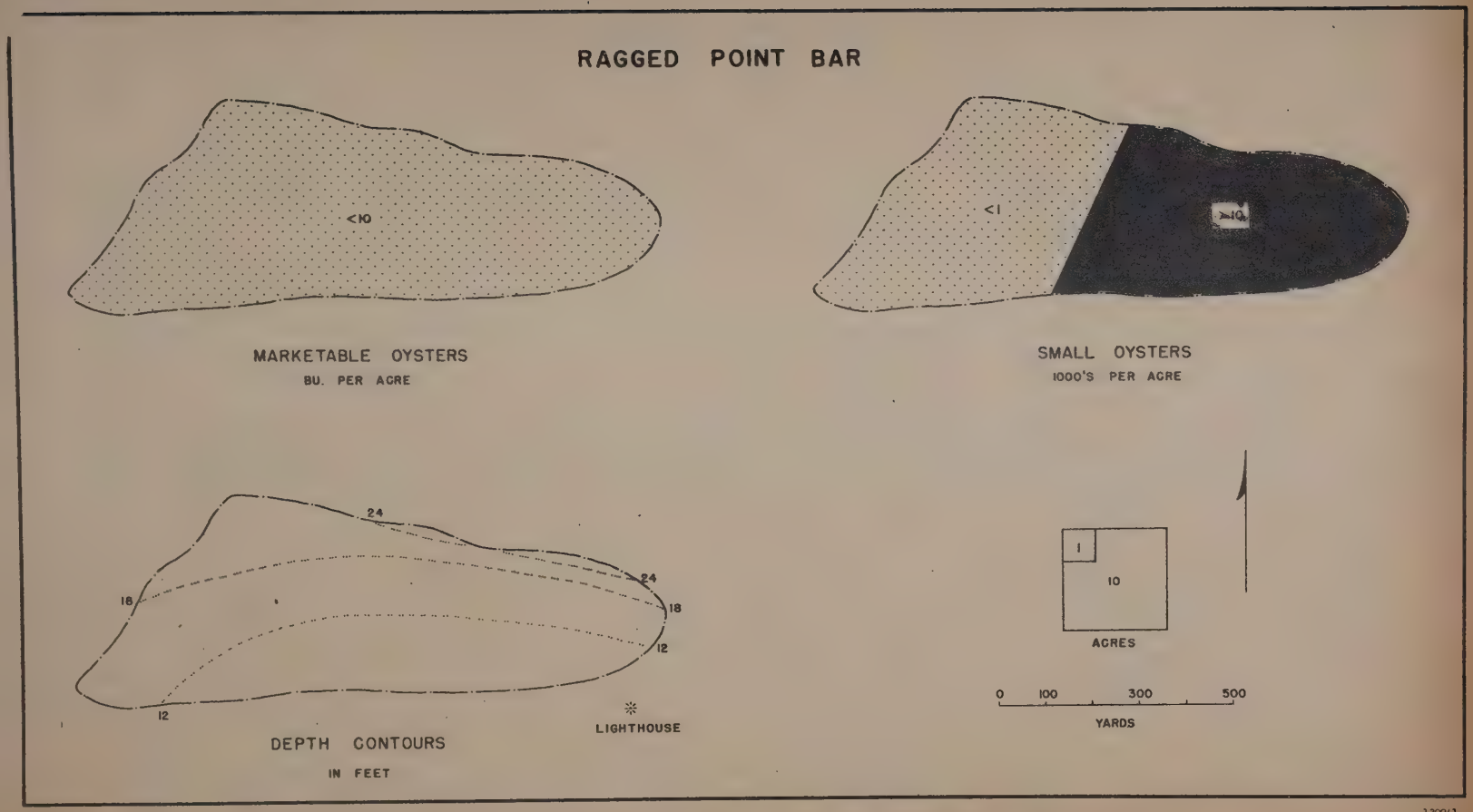

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Figure 26.-- Isopopulation regions and hydrography of Ragged Point Bar.

Table 21.--Ragged Point Bar. Summary of results

Size of oysters	Isopopulation region	Size of region in acres	Percentage of total area	No. dredge hauls	Av. no. oysters per acre	Total no. oysters in region	Av. no. bu. per acre	Total no. bu. in region
3" and larger	<10 bu./acre (Entire bar)	79.5	100.0	15	2126±184.6	169017	7.3±0.97	580.4
less than 3"	<1000/acre	40.3	50.7	8	652±44.6	26276		
	>10000	39.2	49.3	7	12224±1462.1	479181		
	Entire bar	79.5	100.0	15	6358	505457		

Small oysters varied in abundance from only 70 per acre on Blake Creek Bar to 6,358 per acre on Ragged Point Bar. The greatest local concentration of small oysters, however, was found in the northwest corner of Huggins Point Bar, where there were more than 30,000 per acre determined by dredging, and more than 100,000 determined by actual counts on the bottom. Virginia bars averaged 450 more small oysters per acre than the Maryland bars. Five bars on the Maryland side and one on the Virginia side averaged fewer than 1,000 per acre.

Spat from 1942 were lacking on Upper Cedar Point, Old Farms and Wakefield bars, the uppermost bars on the two sides of the river. From Swan Point down to Poseys Bluff along the Maryland shore there was a gradual increase in intensity of setting from 4 to 1,068 per acre. The low figures for Blake Creek and Herring Run bars are in part the result of scarcity of cultch. On Piney Point, St. George, and Cornfield Harbor bars it was impracticable to attempt separating the 1942 spat from other small oysters, but it was certain that there was a set of at least several hundred per acre. Along the Virginia shore the intensity of setting likewise was greatest on the lowermost bars, increasing from 30 per acre on Kingcopsico Point Bar to 636 on Ragged Point. Obviously production of the upper bars in the river cannot be maintained by sets of the magnitude observed for 1942.

On most of the bars examined, marketable and small oysters were not distributed uniformly over the bottom but occurred in definite concentrations. No basic pattern of distribution appears applicable to all the bars. Most often the regions of concentration of large and small occurred in approximately the same places, as at Heron Island, Huggins Point, and Cornfield Harbor. Less frequently small oysters were most abundant, on a different part of the bar than were large oysters. At Swan Point, for example, there was a heavy concentration of marketable oysters in the northern third of the bar with no corresponding concentration of small oysters. At Kingcopsico Point marketable oysters were most abundant in the shallow water and small oysters most abundant in deep water. At Coles Point, likewise, the two size groups of oysters did not occur in greatest abundance at the same places.

A correlation between depth of water and abundance of oysters could not be discerned. Sometimes the concentrations occurred in shallow water, as the heavy concentration of small oysters on the shallow ridge on Sheepshead Bar; at other times the greatest abundance was in deep water, for example the equally great abundance of small oysters along the deep water edge of Kingcopsico Point, the concentration of marketable oysters in the deep water of Heron Island Bar, or the coinciding concentrations of both large and small oysters in deep water at Cornfield Harbor.

These differences in distribution have resulted in a large percentage of the oysters on the various bars being concentrated on a small percentage of the area. Examples for individual bars have been mentioned in the discussion and are readily apparent from tables 5 to 21 and figures 13 to 31. Summaries for the isopopulation regions of all the bars in the river are given in tables 23 and 24.

One-twelfth of all marketable oysters were concentrated on one-fortieth of the total area surveyed. Less than one-fourth of all marketable oysters found were scattered in the isopopulation region of "less than 10 bushels per acre," which aggregated more than half of the total oyster-producing area.

Table 22.--Total number and average number per acre of marketable oysters, small oysters, and 1942 spat found on each of the bars surveyed

Bar	Date surveyed	Area in acres	No. dredge hauls	Marketable oysters (3" and larger)		
				Av. no. bu. per acre	Total no. bu. on bar	Av. no. per acre
Lower Cedar Point	Dec. 11-12, 1942	133.8	50	13.4	1791.6	1722
Swan Point	Dec. 15, 1942 to Jan. 22, 1943	739.1	238	13.7	10147.9	1693
Cobb Island	Dec. 8-10, 1942	291.0	69	4.8	1400.8	616
Sheepshead	Dec. 1-[illegible], 1942	490.0	119	6.7	3289.3	1225
Heron Island	Nov. 19-20, 1942	220.5	41	14.6	3218.8	1023
Huggins Point	Jan. 25-26, 1943	91.2	32	9.1	865.2	1321
Poseys Bluff	Nov. 30, 1942	71.0	22	9.5	701.3	1149
Blake Creek	Nov. 27, 1942	12.4	10	1.1	16.6	171
Herring Run	Nov. 12, 1942	22.2	9	8.8	195.2	1317
Piney Point	June 23-30, 1943	49.3	23	14.0	692.5	2546
St. George	June 21-30, 1943	402.2	74	7.5	3031.9	1004
Cornfield Harbor	July 1-2, 1943	370.6	69	8.3	2815.7	1473
Totals Maryland side of river		2910.1	756	10.1	29275.0	1369
Old Farms	Feb. 2, 1943	133.0	36	5.5	731.5	820
Wakefield	Feb. 3, 1943	102.2	32	7.2	733.0	1005
Kingcopsico Point	Nov. 16, 1942	49.4	15	7.2	354.8	1497
Coles Point	Nov. 26, 1942	114.5	31	11.0	1252.2	2120
Rigged Point	Nov. 17, 1942	79.5	15	7.3	580.4	2126
Totals Virginia side of river		478.6	132	7.8	3751.9	1457
Totals all bars surveyed		3388.7	888	9.7	33026.9	1332

continued on page 75-a

Table 22.--Total number and average number per acre of marketable oysters, small oysters, and 1942 spat found on each of the bars surveyed (Continued)

Bar	Marketable oysters (3" and larger)		Small oysters		1942 spat	
	Total no. on bar	Av. no. per acre	Av. no. per acre	Total no. on bar	Av. no. per acre	Total no. on bar
Lower Cedar Point	230377	129	1669	223370	0	0
Swan Point	1251385	124	3261	2410446	4	2956
Cobb Island	181123	128	524	95400	8	2552
Sheepshead	610116	141	902	449019	75	37350
Heron Island	401624	125	449	98990	*100	22030
Huggins Point	124471	141	4860	457854	703	66223
Posey's Bluff	85045	121	458	33884	1068	79032
Blake Creek	7250	155	70	2968	113	4749
Herring Run	29240	150	1384	30725	*200	4440
Piney Point	125528	182	5730	284968	**---	---
St. George	436178	145	2759	1109555	**---	---
Cornfield Harbor	501718	177	3132	1066727	**---	---
Totals Maryland side of river	3964055	136	2152	6263906	(103)	(219132)
Old Farms	109060	149	1307	240374	0	0
Wakefield	102711	147	555	56751	0	0
Kingcopsico Point	73951	208	3986	196914	*30	1482
Coles Point	242748	180	2095	239053	69	7901
Ragged Point	169017	291	6358	505457	*636	50562
Totals Virginia side of river	697487	186	2590	1259349	(125)	(59945)
Totals all bars surveyed	4661542	142	2214	7503255	(107)	(279077)

*No actual counts made. Figures are estimates based on notes.
**No spat counts made. Oysters densely clustered. Impracticable to separate year classes.

Table 23 also demonstrates that for both sides of the river there was a tendency for scattered oysters to be smaller in size than those occurring at greater population densities. For example, on all the bars marketable oysters in the "less than 10 bushels per acre" region averaged 158 per bushel while those in the "greater than 30 bushels per acre" region averaged 130. On the basis of retarded growth with increasing competition for food, just the opposite condition might be expected. On the other hand it is believed that most of the concentrations of oysters in the river occur where they do because of favorable environmental conditions, which probably influence the rate of growth as well as rates of setting and survival.

Small oysters were more highly concentrated than were the marketable oysters. Three-fifths of all small oysters occurred on only one-sixth of the total area, whereas one-sixteenth of the small oysters were spread over more than half of the total area surveyed, comprising the isopopulation region of "less than 1,000 small oysters per acre."

These inequalities in the distribution of small and marketable oysters indicate that all portions of an oyster bar are not equally successful in maintaining high population densities. Extensive areas on some of the bars had a rather good supply of marketable oysters, but almost no small oysters and spat. Such areas do not appear to be maintaining themselves. Either because of scarcity of cultch, its poor quality, or environmental conditions unfavorable for setting, natural replenishment of population losses in these areas is insufficient to support intensive oystering. Some areas on Sheepshead and Heron Island bars, for instance, had not had a significant setting for many years, possibly not since the heavy sets of 1930 and 1931. On the other hand many of the heavy concentrations of small oysters observed at the time of the survey are directly attributable to a good setting in 1941. It is significant that even at the time of an exceptional setting (say of 1941) many areas received only small numbers of spat, for it indicates that production cannot be uniformly good over the bars when no attempt is made to supplement the natural processes occurring on the bars by suitable methods of oyster cultivation.

COMPARISON OF RESULTS WITH THOSE OF 1928 SURVEY

One of the main objects of this investigation was to ascertain the amount of improvement on the various bars since the survey of 1928. To obtain comparable results it was necessary to use the same method of sampling, and hence, as already explained, a dredge was employed instead of some other instrument which might have given more correct quantitative results.

The survey of 1928 showed the main bars of the river greatly depleted, half of them containing less than one bushel of marketable oysters per acre. (See Table 25). Quantities of oysters on the different bars ranged from a maximum of 2.1 bushels per acre on Lower Cedar Point Bar to only 0.3 on Lakefield. Small oysters were so scarce at this time that for seven bars the per-acre figures could not be calculated. Five other bars had 15 to 30 small oysters per acre. Lower Cedar Point with 903 and Swan Point with 368 were the only bars found with even fair concentrations of small oysters. These two bars were the best in the river in 1928, judged by the quantities of large and small oysters present.

Table 23.--Marketable oysters. Summary of isopopulation regions

Location	Isopopulation region	Area in acres	Percentage of total area	Av. no. bu. per acre	Total bu.	Percentage of total bushels	Av. no. oysters per acre	Total oysters	Percentage of total oysters	Av. no. oysters per bu.
Maryland side of river	0 bu./acre	87.5	3.0	0	0	0	0	0	0	---
	<10 "	1475.1	50.7	3.9	5798.8	19.8	557	822020	20.6	142
	10-20 "	951.9	32.7	14.0	13310.7	45.5	1929	1835970	46.1	136
	20-30 "	319.5	11.0	23.2	7592.3	25.3	5022	964799	24.2	131
	>30 "	76.5	2.6	36.3	2775.2	9.5	4735	361266	9.1	130
	Totals	2910.1		10.1	29275.0		1369	3984055		136
Virginia side of river	0 bu./acre	10.6	2.2	0	0	0	0	0	0	---
	<10 "	328.4	68.6	5.2	1719.8	45.8	1104	362598	52.0	211
	10-20 "	125.6	26.2	13.5	1696.1	45.2	2264	286925	41.1	169
	20-30 "	14.0	2.9	24.0	336.0	9.0	3426	47964	6.9	143
	>30 "	---	---	---	---	---	---	---		
	Totals	478.6		7.8	3751.9		1457	697487		186
All bars surveyed	0 bu./acre	98.1	2.9	0	0	0	0	0	0	---
	<10 "	1805.5	53.2	4.2	7518.6	22.8	657	1184618	25.3	158
	10-20 "	1077.5	31.8	13.9	15006.8	45.4	1746	2122895	45.3	141
	20-30 "	333.5	9.8	23.2	7728.3	23.4	3039	1012763	21.6	131
	>30 "	76.3	2.3	36.3	2773.2	8.4	4735	361266	7.7	130
	Totals	3388.7		9.7	33026.9		1382	4681542		142

Table 24.--Small oysters. Summary of isopopulation regions

Location	Isopopulation region	Area in acres	Percentage of total area	Av. no. oysters per acre	Total oysters	Percentage of total oysters
Maryland side of river	0/acre	110.5	3.8	0	0	0
	<1000 "	1525.1	52.4	256	391007	6.2
	1000-5000 "	836.4	28.7	2293	1917677	30.6
	5000-10000 "	308.7	10.6	6716	2073220	33.3
	>10000 "	129.4	4.4	14465	1871722	29.9
	Totals	2910.1		2152	6263906	
Virginia side of river	0/acre	10.9	2.3	0	0	0
	<1000 "	225.8	47.2	403	91031	7.3
	1000-5000 "	174.1	36.4	2662	463515	37.4
	5000-10000 "	19.6	4.1	5926	116142	9.4
	>10000 "	48.2	10.1	11797	568614	45.9
	Totals	478.6		2590	1239349	
All bars surveyed	0/acre	121.4	3.6	0	0	0
	<1000 "	1750.9	51.7	275	482152	6.4
	1000-5000 "	1010.5	29.8	2357	2381390	31.7
	5000-10000 "	328.3	9.7	6699	2199362	29.3
	>10000 "	177.6	5.2	13741	2440336	32.5
	Totals	3388.7		2214	7503255	

Table 25.--Results of 1942-43 survey compared with those of similar survey in 1928

Bar	Marketable oysters bushels per acre		Small oysters numbers per acre	
	1928	1942-43	1928	1942-43
Lower Cedar Point	2.1	13.4	908	1669
Swan Point	1.5	13.7	368	3261
Cobb Island	0.6	4.8	negligible	324
Sheepshead	0.6	8.7	negligible	902
Heron Island	1.0	14.6	15	449
Muggins Point	1.0	9.4	21	4860
Poseys Bluff	0.7	9.5	negligible	458
Blake Creek	0.6	1.1	15	70
Herring Run	1.8	8.8	16	1384
Old Farms	0.9	5.5	negligible	1807
Lakefield	0.3	7.2	negligible	555
Kingcopsico Point	1.6	7.2	negligible	3986
Coles Point	0.8	11.8	negligible	2095
Ragged Point	1.1	7.3	30	6358
Averages	0.9	10.2*	(98)	1942*

* Averages for 1942-43 survey do not include figures for Piney Pt., St. Georges, and Cornfield Harbor bars.

Fourteen years later in 1942-43 the quantities of both marketable and small oysters on all the bars were considerably greater. Marketable oysters exhibited a 10-fold increase from an average of 0.9 bushels per acre in 1928 to 10.2 in 1942-43. Small oysters showed a 20-fold increase during this period from an average of 98 in 1928 to 1,942 in 1942-43.

Recovery was not equally great on all the bars examined. In marketable oysters, Wakefield Bar showed the greatest relative improvement from 0.3 to 7.2 bushels per acre, a 24-fold increase. Blake Creek exhibited an increase of less than 2 times from 0.6 bushels per acre in 1928 to 1.1 in 1942-43. Other bars showed intermediate amounts of improvement. The populations of marketable oysters on Sheepshead, Heron Island, Poseys Bluff and Coles Point Bar were 14 times greater at the time of the second survey.

With regard to small oysters, the amount of population increase varied from only two times for Lower Cedar Point Bar, which had the greatest number of small oysters in 1928, to 200 times for Huggins Point and Ragged Point, and to possibly a thousand times for Old Farms, Kingcopsico, and Coles Point. Bars on the Virginia side of the river exhibited a much greater average improvement in the quantities of small oysters present than those on the Maryland side of the river. A large proportion of the small oysters in 1942-43 were derived from the heavy set of 1941.

The condition of the oyster bars in 1942-43, undoubtedly, is not the result of a gradual improvement since the survey of 1928, or even since 1931 when the river was closed to dredging. Oysters, like other animals, are subject to fluctuations in population density dependent entirely on natural causes. Floods or enemies may kill large numbers, or occasionally heavy sets may greatly increase the populations on the bars. It is likely that if the present survey had been undertaken in 1937 or 1938 when production as shown by the U. S. Engineer's records was at a peak, larger populations of marketable oysters and smaller populations of undersize oysters would have been found than in the present survey, or if in 1940 or 1941 at a time when annual production in the river was declining there might have been fewer oysters of both classes than were found in 1942-43. Regardless of cause or previous history, many areas in the river, including at least one entire oyster bar, had such small numbers of marketable oysters in 1942-43 as to make dredging unwise from a conservation standpoint.

BIOLOGY OF POTOMAC RIVER OYSTERS

As a result of the two surveys of the Potomac River oyster bars, supplemented with additional observations made by the author in 1943 and 1944, the following facts are known about oyster production in the river:

Distribution: --Oysters grow in the Potomac from the mouth of the river to Maryland Point, a distance of 61 miles, but nearly all commercial oystering occurs from Lower Cedar Point downstream. Physical conditions are not the same in all parts of the oyster-producing region. Salinity is consistently greatest at the mouth of the river, decreasing gradually thence upstream. Occasional severe floods have been reported to cause mortality of oysters on the uppermost bars. Differences in salinities on the various bars, result in different rates of population growth and replenishment, making it inadvisable to attempt managing all the bars in the same way.

Table 26. Number of spat per bushel on natural oyster shell material during each of 4 different years.

Bar \ Year of setting	Spat per bushel			
	1928	1942	1943	1944
Beacon Bar	---	---	---	0
Popes Creek	0	---	---	0
Lower Cedar Point	+	0	3	0
Swan Point	0	+	25	0
Cobb Island	0	1	53	+
Sheepshead	3	4	104	4
Heron Island	0	3	---	0
Huggins Point	0	13	---	0
Poseys Bluff	0	50	---	---
Blake Creek	+	22	---	---
Herring Run	4	8	---	8
Piney Point	---	---	---	---
St. George	---	---	387	32
Cornfield Harbor	---	---	---	---
Old Farms	+	0	---	---
Wakefield	+	0	---	---
Pingcopsico Point	0	+	---	---
Coles Point	+	1	---	0
Ragged Point	3	8	---	0

+ indicates spat present, but fewer than 1 per bushel

Setting: --Table 26 shows that in the four years for which records are available the intensity of setting was greatest towards the mouth of the river, decreasing from there towards the uppermost bars, which completely lacked a setting in 3 of the 4 years. In 1928, for example, no spat were found on Cobb Island, Swan Point, and Popes Creek bars and only 4 in 14 dredge hauls on Lower Cedar Point Bar. In 1942, a few spat were found as far upstream as Swan Point, but none was found on Lower Cedar Point. Likewise in 1944 small numbers of spat were found up to Cobb Island Bar, but none from Swan Point up to Beacon Bar. Even in 1943, which was a good year for setting in the lower part of the river, only 3 spat per bushel were found at Lower Cedar Point Bar.

If this setting gradient can be considered normal for the river, it means that the oyster bars in the lower part of the river receive significant sets more frequently than do the bars in the upper part. The latter receive sets only in exceptional years like 1930, 1931, and 1941. Some areas examined in 1942 had not received a good set for many years.

Because of these differences in rate of population replenishment, commercial production of oysters on the uppermost bars in the river is largely dependent on infrequent heavy settings. It can be expected, therefore, that annual production in this part of the river will be subject to wide variations from one year to another as various dominant year classes come into production and are subsequently reduced in quantity by removal for market.

In the lower part of the river where sets occur more frequently, population levels can be expected to be more stable and annual production subject to smaller yearly variations. Even in this area, however, good sets do not occur every year, as shown by the data for 1928 and 1944.

Another fact which must be taken into consideration is that spat are frequently attached to market-size oysters. For example on the 5 bars examined in the fall of 1943, 60 per cent of the spat that year were attached to legal-size oysters. After one season's growth some of the spat are still small and easily overlooked, or if large enough to be readily seen they have such thin shells that they can seldom be knocked from the market oysters without injury. Consequently, many of them are removed from the river and never contribute to annual production.

Habit of growth: --Where cultch was abundant on the bottom oysters were seldom clustered, and conversely, where cultch was scarce oysters were clustered on these bars where setting is regularly good. On the Maryland side of the river, Lower Cedar Point, Swan Point, and Huggins Point bars had the largest quantities of cultch and no tendency for the oysters to cluster. Cobb Island, Sheepshead, and Heron Island bars had only small quantities of cultch, but the oysters in these localities were not clustered because of the low intensity of setting. From Posey's Bluff to Cornfield Harbor at the mouth of the river, clustering of oysters resulted from the combination of a scarcity of cultch and moderately frequent sets. On Piney Point, St. George, and Cornfield Harbor bars, especially, very few shells or stones on the bottom were without any oysters attached to them.

The 5 bars on the Virginia side of the river were much better supplied with cultch than those on the Maryland side. Ragged Point Bar was almost a

Table 27. Average quantities of cultch material on the various oyster bars in 1942-43

Bar	bushels per acre		
	shells	stones	total cultch
Lower Cedar Point	30	+	30
Swan Point	39	3	42
Cobb Island	3	+	3
Sheepshead	7	1	8
Heron Island	15	+	15
Huggins Point	39	+	39
Poseys Bluff	6	5	11
Blake Creek	3	1	4
Herring Run	15	+	15
Piney Point	4	---	4
St. George	4	+	4
Cornfield Harbor	6	6	12
Old Farms	31	2	33
Lakefield	40	28	68
Kingcopsico Point	40	12	52
Coles Point	42	32	74
Ragged Point	70	+	70

shell pile, with large numbers of broad single oysters in the upper layer. Much of the cultch material on Old Farms and Wakefield bars were composed of mussels and mussel shells. No clustering was found on the Virginia side of the river, except to a minor degree on the stony areas of Coles Point and Kingcopsico Point bars.

Rate of growth: --As indicated by the thickness of the shells compared with the size of the oysters, and the width of the partially calcified fall growth, oysters in the upper part of the river, especially from Lower Cedar Point upstream, grow more slowly than those towards the mouth of the river. Luce in 1928 made a similar observation for the region from Popes Creek to Lower Cedar Point, and noted that (40:128-129), "The condition of the water appears to be favorable for the rapid growth of oyster spat, but not for the growth of marketable oyster." It seems likely that the formerly large accumulations of small-size oysters at the head of the river resulted from the slow growth of the occasional sets occurring in this region, rather than from frequent settings, as formerly believed.

Enemies: --Oysters in the Potomac are relatively free of enemies and parasites. On the basis of available information the worm, Polydora, and boring sponges are the most important enemies followed by the oyster crab. All three of these organisms are most abundant and active in the lower part of the river.

Polydora websteri was found from the mouth of the river up to Beacon Bar, although from Lower Cedar Point upstream it occurred only in very small numbers. It is most abundant in the lower part of the river, where it may possibly damage the oysters and retard their growth rate.

The boring sponge, Cliona truitti, was found as far upstream as Sheepshead and Kingcopsico Point bars. It was most abundant and active on the lowermost bars in the river, where many shells were perforated by their organism.

The oyster crab, Pinnotheres ostreum, has been found as far upstream as Cobb Island on the Maryland side and Coles Point on the Virginia side. Crabs were most abundant on Blake Creek Bar, where 6 specimens were found in a sample of 25 oysters. No oyster was found with more than one crab.

Examinations were made for Nematopsis in 13 oysters from St. Mary's River without finding the parasite. Since this sporozoan is reported widely distributed in Chesapeake Bay, it probably also occurs in the Potomac River.

The trematode worm, Bucephalus, was found in the gonads of 3 oysters from Chicken Cock Bar in St. Marys River and in one from St. George Bar.

The starfish, Asterias forbesi, has been found in the lower part of the Chesapeake Bay below the mouth of the Rappahannock River (2a:365) but never as far up the Bay as the Potomac.

Drills, Urosalpinx cinerea and Eupleura caudata, are lacking in the Potomac because salinity is not sufficiently high throughout the year to permit the survival of these snails.

CONCLUSIONS

The study of aquatic resources and determination of their population densities presents greater technical difficulties than those usually encountered in similar studies of agricultural resources. Nevertheless, by the examination of a large number of samples from the river bottom a good idea can be obtained of conditions existing on the bottom. On the basis of the present studies and of supplementary information gained through examination of the meager literature, the following facts regarding the oyster-producing region of the Potomac River are apparent.

The oyster resources of the Potomac have been continually shrinking since the time of highest production in the 1880's. Entire bars have become unproductive, extensive areas of others no longer produce oysters, and a large proportion of the remaining areas have only small quantities of oysters. The latter conditions, observed in 1942-43, are clearly shown on the various maps accompanying this report. From a consideration of the evidence produced by this survey, it can be inferred that the present low annual production is the result both of the decrease in acreage of producing bottom and decrease of population densities on the bars.

The natural rate of replenishment is low on many areas. Available records indicate that setting is normally light or lacking entirely towards the head of the oyster-producing region, and occasionally light on nearly all the bars in the river. Production of oysters from the uppermost bars is largely dependent on infrequent heavy sets. The maximum annual production of a natural bar is limited by the intensity of setting, because for any year class the number of marketable oysters removed can never equal the number of spat which set on the bar. In fact, because of mortality from various causes the number of large oysters removed will always be smaller than the number of young oysters.

Many areas in the lower part of the river where good sets occur rather frequently do not have sufficient cultch to provide for the best possible utilization of these sets. Larger quantities of cultch would be expected to result in a greater number of oysters from any spatfall, and would tend to keep the oysters from becoming clustered.

As a result of the low intensity of setting and the scarcity of cultch in many areas, annual production in the Potomac can be expected to continue at a rather low level. Since some of the largest bars occur upstream where setting is infrequent, it is likely that most fluctuations in production will result from exploitation of occasional heavy sets on these bars. The small amount of improvement between 1928 and 1942 indicated that the natural rate of replenishment is very slow and cannot be depended upon to restore the bars to their former productivity.

A sustained increase in annual production can be brought about only by improving conditions on the various bars according to their individual needs; for it is apparent that all the bars in the river, differing as they do in intensity of setting, rate of growth of oyster, and amount of cultch present, cannot be treated alike. The sets occurring naturally in the river can be made of greater value to the industry by planting shells on those areas from

Cobb Island to the mouth of the river shown by the survey to be deficient in cultch. Production on the bars from Heron Island to Lower Cedar Point could be materially increased and stabilized by planting seed oysters on areas with insufficient numbers of small oysters. Quantities of oysters resulting from the infrequent heavy settings in the former seed area located above the Potomac River bridge could be sold either as seed or market oysters depending on their size, or advantageously transplanted to bars further downstream, where faster growth and a better quality ouster would result.

If increased production of oysters from the Potomac is sincerely desired by Maryland and Virginia, then, the foremost problem confronting the States is the formulation of an agreement for cooperatively managing these oyster resources according to the needs of the individual bars. Under the present unsatisfactory condition resulting from the mutual suspicion that anything done by one State would bring greater benefit to the other, even effectively enforcement of the fishery laws is impossible. Until close cooperation between the States can be realized there is little likelihood of any substantial improvement in the Potomac River oyster resources or production.

ANNOTATED LIST OF PLANTS AND ANIMALS

During the course of the survey, although no special attempt was made to collect all the various invertebrates associated with the oyster, specimens of most of the organisms encountered were preserved and transferred to the collections of the U. S. National Museum. The following annotated list is based on the identification of these specimens by members of the Museum staff and others.

1. Sponges. Identifications (except Cliona) by Dr. M. W. deLaubenfels.

   Microciona prolifera (Ellis and Sollander). Requires water of rather high salt content. Found only on Cornfield Harbor bar.

   Haliclona permollis (Bowerbank). Found upstream as far as Poseys Bluff. Most abundant in vicinity of St. Marys River.

   Cliona truitti (Old). A boring sponge most abundant and active in lower part of Potomac. Live sponges found up to Sheepshead and Kingcopsico. Sponge-riddled shells found a little further upstream, but no recent activity. Old reported boring sponges from several locations in the Wicomico and St. Marys rivers.

2. Coelenterates. Hydroids identified by Dr. C. McLean Fraser.

   Clytia longicyatha (Allman). Widely distributed in small numbers as far upstream as Lower Cedar Pt. Occurs chiefly in late summer and fall.

   Thuiaria argentea (Linn.) Only one specimen obtained from lower part of Potomac.

   Bimeria tunicata (Fraser). Only one specimen from Lower Cedar Pt.

Anemones (unidentified). Abundant and widely distributed upstream at least to Swan Pt.

Dactylometra quinquecirra (L. Agassiz). Abundant in late summer from Ragged Pt. downstream. Less abundant above Ragged Pt.

3. Ctenophores. No specimens collected for indentification.

Mnemeopsis sp. Occurs throughout the summer, and is sometimes very abundant locally.

Beroe sp. A late summer and fall form present in small numbers.

4. Flatworms.

Stylochus ellipticus (Girard). Identified by Dr. Libbie Hyman. Can be found in most areas in small numbers.

Bucephalus sp. Several specimens from Chicken Cock Bar in St. Marys River and St. George Bar in lower Potomac.

5. Nemerteans. Identified by Dr. Wesley R. Coe.

Micrura leidyi (Verrill). Several specimens from mud in shallow water near Sheepshead Bar.

6. Bryozoa. Identified by Dr. Raymond C. Osburn

Acanthodesia tenuis (Desor).

Membranipora crustulenta (Pallas). Both species are important fouling organisms on shell organisms. They were present on all oyster areas examined, being somewhat less abundant in the upper part of the river.

7. Polychaete worms. Identified by Dr. Olga Hartman.

Neanthes succinea (Frey and Leuckart). Abundant on all bars examined. Found commonly in burrows in the oyster shells.

Polydora websteri (Hartman). Produces mud blisters on inner surfaces of shells of living oysters. Abundant from Cobb Island downstream. Less abundant from Swan Pt. upstream.

Nereis culveri (Webster). Taken only in shallow water near Sheepshead Bar.

Scoloplos viridis (Verrill). Generally distributed from Sheepshead Bar downstream. Not abundant.

Nereiphylla fragilis (Webster). Taken only at Poseys Bar.

8. Leech. Identified by Dr. J. Percy Moore.

Nomibdella sp. One specimen from St. George Bar.

9. Amphipods. Identified by Mr. Clarence R. Shoemaker

Corinocammarus mucronatus (Say). Common and widely distributed.

Corophium lacustre (Vanhöffen). Occurs in fair numbers upstream to Lower Cedar Point.

Grubia compta (Smith). Specimens were obtained from Sheepshead, Cords Flats, Huggins Pt., and Heron Island. Probably widely distributed.

Melita nitida (Smith). Generally distributed on all bars.

Gammarus sp. One specimen from shallow water along Cobb Island shore, and one from Old Farms Bar.

Caprella scutifrons Latr. Abundant in growths of Clytia longicyatha on Huggins Pt. Bar.

10. Isopods. Identified by Mr. Jo. O. Maloney.

Cassidinidea lunifrons (Rich.). Abundant and widely distributed up to Lower Cedar Pt.

Erichsonella attenuata (Harger). Generally distributed in areas containing submerged spermatophytes.

Cyathura carinata (Kryer). One specimen from muddy sand in 1-1/2 ft. of water near Sheepshead Bar.

11. Decapods. Identified by Dr. Waldo L. Schmitt.

Palaemonetes carolinus (Stimpson). Specimens obtained from Sheepshead, Huggins Point, and Ragged Point Bars. Common in "grass."

Palaemonetes vulgaris (Say). One specimen from Piney Point Bar.

Crago septemspinosus (Say). One specimen from "grass" on Sheepshead Bar.

Pinnotheres ostreum (Say) Present from mouth upstream to Cobb Island on Maryland side of river and to Coles Point on Virginia side. All specimens were females except for one male from St. George Bar.

Eurypanopeus depressus (Smith). Present and usually abundant on all bars examined.

Rithropanopeus harrisii (Gould). Specimens obtained from Sheepshead Coles Point and Poseys Bluff Bars and from Smith Creek. Not so abundant as Eurypanopeus.

Callinectes sapidus (Rathbun). The edible "Blue crab," abundant over the entire oyster-producing area.

Sesarma cinereum (Bosc). Abundant on shore of Smith Creek.

12. Molluscs. Identified by Dr. Harold Rehder.

Odostomia (Menestho) trifida (Totten). Generally distributed upstream to Cobb Island Bar.

Nassarius vibex (Say). Specimens from Poseys Bluff, St. George, and Cornfield Harbor. Abundant in shallow water at Cornfield Harbor.

Littorina irrorata (Say). Abundant on shells, pilings, and vegetation at edge of water.

Crepidula convexa (Say). Scattered from Piney Pt. downstream, including lower portions of St. Marys River and Smith Creek.

Melampus lineatus (Say). Collected only at Millers Wharf in Smith Creek on grass along shore.

Epitonium linectum (Say). Collected at Sheepshead Bar.

Mya arenaria (Linne). Small specimens from Piney Pt., Heron Island, Neale Sound and Cobb Island Bar. Occurs abundantly on hard mud or sand shoal areas in the Potomac as evidenced by frequency of shells in dredge hauls.

Brachidontes (Ischadium) recurvus (Rafinesque). Found on all bars examined. Most abundant on Old Farms and Wakefield bars where many oysters and shells were completely covered. Less abundant above Swan Pt. and below Piney Pt.

Volsella demissa (Dillwyn.) Generally distributed among intertidal vegetation upstream at least to Cobb Island.

Volsella (Amygdalum papyria (Conrad). Specimens collected only near mouth of St. Marys River.

Mulinia lateralis (Say). Specimens from Sheepshead, Cobb Island, Coles Pt., and Ragged Pt.

Congeria (Mytilopsis) leucophaeta (Conrad). Extends from Cobb Island and Old Farms upstream, increasing in abundance somewhat towards the head of the oyster producing region.

Arca campechiensis (Gmelin). Collected at Huggins Pt. Bar.

Macoma balthica (Linne). Dredged from Sheepshead Bar. Abundant in mud in shallow water near Sheepshead Bar and Cobb Island.

Tellina tenera (Say) Collected in shallow water near Sheepshead Bar and at Cobb Island.

Gemma gemma manhattensis (Prime). Collected only at Blake Creek Bar.

Corambella sp. Generally distributed in small numbers upstream to Heron Island Bar.

13. Tunicates. Identified by Dr. Willard G. Van Name.

Molgula manhattensis (De Kay). Has been collected as far upstream as Cobb Island. Most abundant in lower part of river. Abundant on Rogged Pt. Bar in 1944.

14. Spermatophytes. Identified by Dr. Conrad V. Morton.

Potamogeton pectinatus (Linne). Widely distributed and abundant from Swan Pt. to the mouth of the Potomac. Forms dense beds in some areas.

Potamogeton perfoliatus var. bupleuroides (Fernald) Terwell. Frequently associated with P. pectinatus but much less abundant.

Ruppia maritima (Linne). Distributed from mouth of river at least to Sheepshead Bar.

Zostera marinus (Linne). Quite abundant from Piney Pt. downstream. Piney Pt. Bar is sometimes called Sea Oar Hollow Bar, because of the large quantities of Zostera blades frequently observed at this location.

15. Algae. Not identified as to species, but the following genera were observed to have wide distribution: Ulva, Enteromorpha, Polysiphonia, Ceramium, Desya, Gracilaria. Representatives of the last four genera were most abundant towards the mouth of the river.

Identification of the barnacles and anemones has not yet been completed.

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